NASA’s Implementation Plan for International Space Station Continuing Flight

A periodically updated document demonstrating our commitment to application of the **Columbia** ***Accident Investigation Board recommendations in support of safe continuing flight of the International Space Station***

October 28, 2003

An electronic version of this implementation plan is available at www.nasa.gov

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Preface

The loss of the Space Shuttle *Columbia* and its crew was devastating for the entire NASA family. For the International Space Station (ISS) Program, finding our way through this tragic loss begins with an unwavering commitment to learn from this tragedy. We will reshape the ISS Program based on those lessons, and carry out the Administrator's directive to continue our mission of building, operating and performing research on the ISS effectively and safely.

We are committed to those actions that will help return the Shuttle to flight and, in turn, will support our exploration and science objectives. The crew of *Columbia* was dedicated to this vision of science and exploration and devoted their lives to further it. It is our job to continue their vision.

This document details the ISS plans for accepting the findings, complying with the recommendations applicable to ISS, and embracing the *Columbia* Accident Investigation Board (CAIB) Report. The CAIB Report identifies systemic issues that directly or indirectly affect the way we plan, develop, and operate. We will address those CAIB issues and describe how the ISS Program is moving forward on a comprehensive set of process improvements.

This ISS Continuing Flight Implementation Plan captures a snapshot of our review of lessons learned from the *Columbia* accident and how we will work to implement these lessons into the ISS Program. We will periodically update this document as our review and reassessment of procedures and processes identifies needed changes and technical options for improvements. Updates to this plan will reflect new understanding, increased maturity, and decisions. We will also update this document to include responses to the CAIB observations and other CAIB Report Volumes as they are released.

The response summary provides an overview of the ISS Program's response to the initial CAIB recommendations and to process improvement actions. Part 1 provides a detailed discussion of activities undertaken by NASA to implement the applicable CAIB recommendations. Part 2 discusses additional NASA actions taken as a result of internal reviews and working group recommendations in addition to those made by the CAIB and, in the next update, will contain the Board's observations.

The *Columbia* tragedy serves as strong reminder that space flight is harshly unforgiving of engineering deficiencies, overconfidence, system or human error, and inaccurate risk assessments. The ISS Program's part in the return to flight efforts requires us to continue to identify, understand, control, and mitigate the risk unique to the ISS while accomplishing the mission entrusted to us. We do so with the memories of our dear friends and colleagues—the crew of STS-107—serving as both an inspiration and an imperative to succeed safely.

Summary

The *Columbia* Accident Investigation Board (CAIB) addressed both the direct and the contributing causes of the *Columbia* accident and documented its results in the CAIB Report, issued in August 2003. The CAIB Report addressed issues that are critical not only for the Space Shuttle Program, but for NASA as a whole. NASA accepts the findings, will comply with the recommendations, and embraces the Report. In addition, NASA is analyzing the report for applicability to other programs including the International Space Station (ISS) Program.

The Space Shuttle Return to Flight Planning Team is focusing on the actions necessary to return the Shuttle safely to flight. ISS Program personnel are participating fully in these important initiatives, and their joint effort is addressed in Volume 1 of NASA's response to the CAIB Report: NASA's Implementation Plan for Space Shuttle Return to Flight and Beyond. In addition, NASA is pursuing an in-depth assessment of its organization with the objective of aggressively implementing corrective actions. NASA chartered the ISS Continuing Flight Team (CFT) to review the CAIB Report and determine the areas that are applicable to the ISS Program and ensure there are actions in place addressing those areas. The purpose of this document—Volume 2 of NASA's response to the CAIB Report: NASA's Implementation Plan for International Space Station Continuing Flight—is to document these findings and our progress towards completion of necessary actions.

As with Volume 1, Volume 2 will continue to evolve as our understanding of the activity needed to address each issue matures. We anticipate periodically updating Volume 2 to reflect changes to the plan and progress toward implementing the lessons learned from the CAIB Report as they relate to the ISS Program. Volume 2 updates will also include responses to the observations and any additional relevant lessons from the remaining volumes of the CAIB Report that are scheduled for release soon. Reaping the lessons learned from the *Columbia* accident and the CAIB's results started immediately after the accident. While the CAIB was conducting its investigation, the ISS Program began an intensive effort to examine its own processes and operations under a continuous improvement initiative. One of the objectives was to identify the existence of any risk that has not been reduced to the lowest level and to focus management attention on the residual risks that cannot be eliminated. As the CAIB released its preliminary results, the ISS Program assessed them for applicability. Other continuous improvement activities were derived from the experience the ISS Program has gained from 3 years of crewed ISS operations and 5 years of ISS system operation.

Continuing Flight Team Assessment and Implementation Plan Organization

The Continuing Flight Team (CFT) assessed every CAIB recommendation and observation for applicability to the ISS. Some of the CAIB recommendations were specific to Space Shuttle design or processes. Others affect NASA safety and engineering processes as a whole. The CAIB Report provides valuable lessons learned applicable to the ISS Program. Part 1 of this volume addresses the CAIB recommendations that were found to be applicable to the ISS. Although some of these recommendations do not specifically apply to the ISS, their underlying intent provides valuable insights that contribute to improving ISS processes. Part 2 of this volume addresses many of the ISS Program areas of continuous improvement. The CAIB observations will be addressed in Part 2 in the next revision.

Where the underlying intent of any recommendation is addressed by another recommendation documented in Part 1 or a continuous improvement area documented in Part 2, the location of the text that addresses the subject will be referenced.

Reaping the Benefits of the IMCE Assessment

The CAIB report makes several references to the ISS Management and Cost Evaluation (IMCE) Task Force that conducted an in-depth review of the ISS Program cost, schedule, technical, and management infrastructure. This Task Force was a direct result of the President's fiscal year 2002 (FY2002) Budget Blueprint, which laid groundwork for attaining cost control and regaining ISS Program credibility needed to fulfill the ISS full potential and international commitments. The Task Force conducted independent assessments of the ISS Program and provided 12 recommendations to NASA in an IMCE report released on November 1, 2001. These recommendations provided a roadmap to improve ISS Program management and cost controls.

In response to the IMCE findings and recommendations, the ISS Program implemented a reliable and effective cost-estimating and management system that provides a structured and disciplined program to manage cost and risks.

ISS Operations Are Ongoing

The grounding of the Space Shuttle fleet following the loss of *Columbia* has had a profound effect on the ISS Program. The loss of capabilities provided by the Space Shuttle has resulted in a delay in the assembly of ISS and has greatly reduced the cargo mass available for resupply and research. The loss of down mass has impacted our ability to return failed hardware, results of scientific investigations, and environmental samples. In response to these challenges, a plan to allow continued crewed operations of the ISS was developed and agreed to by all ISS Partners. This plan requires the Russian Progress spacecraft be used to supply cargo and crews be rotated with the Russian Soyuz vehicle. This plan is being implemented with the cooperation and efforts of all Partners.

On October 18, 2003, the Expedition 8 crew was launched on a Russian Soyuz vehicle to the ISS. The two-person crew, comprised of Commander Mike Foale and Flight Engineer Alexander Kaleri, is scheduled to spend 192 days on board the ISS, conducting research, and maintaining ISS systems. The Expedition 7 crew, Commander Yuri Malenchenko and ISS Science Officer Edward Lu, will return to Earth on October 28, 2003, after spending 185 days on orbit. As a taxi crew member on the ISS crew exchange, Spanish European Space Agency Astronaut Pedro Duque will spend 8 days on the ISS performing a variety of experiments. The ISS Program team remains focused on conducting its mission while safely supporting our crew.

ISS Partnership Is Strong

The ISS International Partnership has stepped up to the challenge of keeping the ISS crewed and operating safely as NASA works through the activities to return the Space Shuttle to flight. Although the grounding of the Space Shuttle has been a challenge to ISS operations, the spirit of partnership that has built the ISS will sustain the ISS through this difficult period.

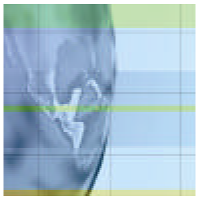
The integrated international nature of the ISS Program and its operation has emphasized the need for clear communication and coordination at all levels of the Program structure. One of the keys to the success of the ISS Program, due to its integrated international nature, has been establishing and maintaining clear communications and coordination among the International Partners at all levels of the Program structure. As we gain experience in operating the ISS, we realize improvements in communication that lead to an increased efficiency. The grounding of the Space Shuttle fleet, and the associated constraints on up mass and down mass, has brought further improvements in communication among the Partner teams.

NASA will continue to work closely with its International Partners and keep the lines of communication open as the ISS Program implements process improvements and enhancements as a result of lessons learned from *Columbia*. These changes will be implemented within the framework of our international agreements.

Conclusion

This initial ISS CFT Implementation Plan summarizes the results of our review to date of the lessons learned from the loss of *Columbia* and the ISS continuous improvement initiative. It identifies current responsive implementations, outlines technical and management options under consideration to improve the ISS Program and reduce risk, and identifies forward work where solutions are in development.

As ISS continues to fly, the safety of the crew and the vehicle are paramount. As we learn from the loss of *Columbia* and its crew, we must remember that while the Shuttle fleet may be grounded, we still have U.S., Russian, and other International Partner astronauts flying in space. Providing a safe environment for them to conduct research and operate the ISS is our most critical challenge.



Response Summaries

Part 1 - Responses to the Columbia *Accident Investigation Board's Recommendations*

The following section provides brief summaries of the Continuing Flight Team's (CFT's) response to each *Columbia* Accident Investigation Board (CAIB) recommendation in the order in which they appear in the CAIB Report. Additional detail on each response can be found in the following sections of this implementation plan. This is a preliminary plan that will be periodically updated.

THERMAL PROTECTION SYSTEMS

R3.2-1 Initiate an aggressive program to eliminate all External Tank Thermal Protection System debris-shedding at the source with particular emphasis on the region where the bipod struts attach to the External Tank. [RTF]

Although this recommendation addresses threats from loose hardware generated during the launch of the Space Shuttle, the International Space Station (ISS) Program recognizes that the safety of the ISS vehicle and other visiting vehicles also depends on avoidance of threats from uncontrolled hardware. ISS is designed to avoid debris generation by the orbital vehicle and visiting vehicles (Soyuz, Progress, Automated Transfer Vehicle, H-II Transfer Vehicle). In addition, requirements impose limits upon generation of external contaminants.

Operational steps are taken to preclude threats associated with potential debris sources. Existing risk mitigation measures are in place to control and assess this potential hazard. ISS Program management, design engineers, crew members, flight controllers, training instructors, and safety teams continue to provide assurance of this risk mitigation.

R3.3-2 Initiate a program designed to increase the Orbiter's ability to sustain minor debris damage by measures such as improved impact-resistant Reinforced Carbon-Carbon and acreage tiles. This program should determine the actual impact resistance of current materials and the effect of likely debris strikes. [RTF]

The underlying intent of this recommendation is addressed by Part 2, ISS Continuous Improvement Action ISS-8.

R3.3-1 Develop and implement a comprehensive inspection plan to determine the structural integrity of all Reinforced Carbon-Carbon system components. This inspection plan should take advantage of advanced non-destructive inspection technology. [RTF]

The underlying intent of this recommendation is addressed in Part 1, R4.2-4.

R6.4-1 For missions to the International Space Station, develop a practicable capability to inspect and effect emergency repairs to the widest possible range of damage to the Thermal Protection System, including both tile and Reinforced Carbon-Carbon, taking advantage of the additional capabilities available when near to or docked at the International Space Station.

For non-Station missions, develop a comprehensive autonomous (independent of Station) inspection and repair capability to cover the widest possible range of damage scenarios.

Accomplish an on-orbit Thermal Protection System inspection, using appropriate assets and capabilities, early in all missions.

The ultimate objective should be a fully autonomous capability for all missions to address the possibility that an International Space Station mission fails to achieve the correct orbit, fails to dock successfully, or is damaged during or after docking. [RTF]

The ISS Program is working with the Space Shuttle Program to develop a method to inspect and effect emergency repairs to the Space Shuttle Thermal Protection System. The ISS Program has examined its on-orbit vehicle inspection requirements and implementation details to assess their adequacy. These requirements were found to be inadequate in light of the Space Shuttle fleet grounding. In response to this situation, the ISS Program has developed a systematic approach for performing an exterior imagery survey using on-board assets.

The ISS Program has instituted a plan to periodically perform external surveys of the ISS using on-board assets. The ISS external survey using external cameras is complete. Results indicate that ISS exterior hardware is generally performing as expected and no significant anomalies have yet been revealed. The remainder of the exterior survey, using robotic assets and crew observation, must be completed and analyzed, and results must be reported. It is anticipated that these inspections will be performed by April 2004. The frequency at which the survey is performed will be established and adjusted based on the survey findings.

R3.3-3 To the extent possible, increase the Orbiter's ability to successfully re-enter Earth's atmosphere with minor leading edge structural sub-system damage.

The underlying intent of this recommendation is addressed in Part 1, R4.2-4.

R3.3-4 In order to understand the true material characteristics of Reinforced Carbon-Carbon components, develop a comprehensive database of flown Reinforced Carbon-Carbon material characteristics by destructive testing and evaluation.

The underlying intent of this recommendation is addressed in Part 1, R4.2-4.

R3.3-5 Improve the maintenance of launch pad structures to minimize the leaching of zinc primer onto Reinforced Carbon-Carbon components.

This recommendation is not applicable to the ISS.

R3.8-1 Obtain sufficient spare reinforced carbon-carbon panel assemblies and associated support components to ensure that decisions on reinforced carbon-carbon maintenance are made on the basis of component specifications, free of external pressures relating to schedules, costs, or other considerations.

The ISS has no Reinforced Carbon-Carbon panels; however, there are a number of systems that are required to provide life support and sustain operations. Focusing on the importance of spares to minimize decisions that would be subject to schedule pressure, the ISS Program reviewed its spares provision plans and processes for adequacy. The ISS Program plans and processes were determined to be adequate.

After the Shuttle accident and in response to the *Columbia* Accident Investigation Board recommendations, the ISS Program has reviewed its logistics and maintenance plans to ensure that sparing plans are adjusted for the extended Space Shuttle downtime. This process continues as the downtime is extended and critical decisions affecting spares must be made. A spare is currently pre-positioned on orbit for many of these critical orbital replaceable units (ORUs). Since the loss of *Columbia*, Progress and Soyuz capacity has limited the ability to deliver limited-life items and large ORUs.

R3.8-2 Develop, validate, and maintain physics-based computer models to evaluate Thermal Protection System damage from debris impacts. These tools should provide realistic and timely estimates of any impact damage from possible debris from any source that may ultimately impact the Orbiter. Establish impact damage thresholds that trigger responsive corrective action, such as on-orbit inspection and repair, when indicated.

While the CAIB's action was specific to the debris impacts on a Shuttle, the ISS Program initiated steps to assess all ISS analytical models and tools that are used to support on-orbit operations, anomaly resolution, and decision-making processes. ISS Program boards are reviewing the models to ensure that the model bases assumptions, limitations, and boundary conditions are understood and are acceptable. The ISS Program boards will address any identified augmentations required as the result of their assessment.

R3.4-1 Upgrade the imaging system to be capable of providing a minimum of three useful views of the Space Shuttle from liftoff to at least Solid Rocket Booster separation, along any expect-

ed ascent azimuth. The operational status of these assets should be included in the Launch Commit Criteria for future launches. Consider using ships or aircraft to provide additional views of the Shuttle during ascent. [RTF]

The underlying intent of this recommendation is addressed in Part 1, R6.3-2 and R6.4-1.

R3.4-2 Provide a capability to obtain and downlink high-resolution images of the External Tank after it separates. [RTF]

The underlying intent of this recommendation is addressed in Part 1, R6.3-2 and R6.4-1.

R3.4-3 Provide a capability to obtain and downlink high-resolution images of the underside of the Orbiter wing leading edge and forward section of both wings' Thermal Protection System. [RTF]

The underlying intent of this recommendation is addressed in Part 1, R6.3-2 and R6.4-1.

R6.3-2 Modify the Memorandum of Agreement with the National Imagery and Mapping Agency (NIMA) to make the imaging of each Shuttle flight while on orbit a standard requirement. [RTF]

The ISS Program will take advantage of national assets to support on-orbit assessment of the ISS external condition.

NASA has already concluded a Memorandum of Agreement with the National Imagery and Mapping Agency that provides for on-orbit assessment of the condition of each Orbiter Vehicle as a standard requirement. NASA has initiated discussions across the interagency community to explore the use of appropriate national assets to evaluate the condition of the Orbiter Vehicle. In a similar manner, this effort has been applied to the ISS vehicle for ascertaining ISS status, upon request.

Since this action may involve receipt and handling of classified information, the appropriate security safeguards will be observed during its implementation.

R3.6-1 The Modular Auxiliary Data System instrumentation and sensor suite on each Orbiter should be maintained and updated to include current sensor and data acquisition technologies.

The ISS Program recognizes that vehicle performance characterization data are required through the life of the vehicle. The ISS depends on telemetry to a greater degree than the Shuttle because the ISS remains continuously in orbit. ISS systems performance assessment instrumentation are combined with operational telemetry requirements to provide a consolidated telemetry capability.

The ISS Program has assessed the vehicle performance characterization instrumentation. Concepts are being evaluated to enhance our ability to characterize the ISS vehicle performance over its lifetime in critical areas, such as structural performance.

R3.6-2 The Modular Auxiliary Data System should be redesigned to include engineering performance and vehicle health information, and have the ability to be reconfigured during flight in order to allow certain data to be recorded, telemetered, or both, as needs change.

This recommendation is addressed in a consolidated response to R3.6-1.

R4.2-2 As part of the Shuttle Service Life Extension Program and potential 40-year service life, develop a state-of-the-art means to inspect all Orbiter wiring, including that which is inaccessible.

The nature of the ISS system dictates that physical wiring inspections be performed on orbit. Once operational, the environment that ISS wiring is exposed to is limited to conditions on orbit. Internal wiring is susceptible to damage when it, or hardware nearby, is manipulated through normal daily activity on the ISS. Plans are in place to perform routine inspection of high traffic area wiring as part of normal ISS systems maintenance. External wiring was designed to operate in the micrometeoroid and orbital debris environment of low Earth orbit.

Even though the ISS elements on orbit have only been in place for 5 years, the ISS Program will evaluate whether additional routine wiring inspections should be implemented in response to aging concerns.

R4.2-1 Test and qualify the flight hardware bolt catchers. [RTF]

The underlying intent of this recommendation is addressed in Part 2, ISS Continuous Improvement Action ISS-12.

R4.2-3 Require that at least two employees attend all final closeouts and intertank area hand-spraying procedures. [RTF]

ISS procedures in place for processing of Boeing hardware have been reviewed and determined to meet the CAIB recommendation for quality control of critical procedures. These guidelines are being formulated into a Standard Practice and Procedure that will apply to all ISS Program hardware processed at Kennedy Space Center (KSC). Documentation to extend the applicability to all ISS Program hardware processed at KSC is scheduled for release in November 2003. ISS requires independent closeout of all flight hardware at KSC.

R4.2-4 Require the Space Shuttle to be operated with the same degree of safety for micrometeoroid and orbital debris as the degree of safety calculated for the International Space Station. Change the micrometeoroid and orbital debris safety criteria from guidelines to requirements.

Micrometeoroid and orbital debris (MMOD) is recognized as a continuing concern for ISS, Shuttle, and other spacecraft. The ISS was designed for long-term exposure to both micrometeoroids and orbital debris. Robust shielding protection and operational procedures are in place on ISS, or will be implemented during upcoming assembly missions, to reduce the risk of MMOD-induced threats to the crew and vehicle. In addition, ISS hardware is designed to allow MMOD shielding to be augmented over the life of the Program.

R4.2-5 Kennedy Space Center Quality Assurance and United Space Alliance must return to the straightforward, industry-standard definition of "Foreign Object Debris" and eliminate any alternate or statistically deceptive definitions like "processing debris." [RTF]

ISS Program engineers are working with their Shuttle counterparts to review applicable standards and develop a Foreign Object Debris (FOD) Control Plan in response to the CAIB report. Working closely with Shuttle engineers will ensure a consistent universal approach to minimize the risk of FOD to flight operations and ISS performance.

R6.2-1 Adopt and maintain a Shuttle flight schedule that is consistent with available resources. Although schedule deadlines are an important management tool, those deadlines must be regularly evaluated to ensure that any additional risk incurred to meet the schedule is recognized, understood, and acceptable. [RTF]

Our priorities will always be flying safely and accomplishing our missions successfully. We will fly only when the necessary milestones are achieved, and we will not be driven by planning schedules.

The ISS Program has adopted a development and operations schedule that is consistent with available resources; this schedule is necessarily tied to that of the Shuttle. The two Programs' top-level schedules are integrated and assessed for risk through actions of the Joint (Shuttle-Station) Program Requirements Control Board. Furthermore, through the implementation of several ISS Program control processes and tools, technical, cost, and schedule risks and their mitigation plans are assessed regularly. The data are placed in the One NASA Management Information System so that the senior managers in the Space Flight Enterprise can virtually review schedule performance indicators and risk assessments on a real-time basis.

R6.3-1 Implement an expanded training program in which the Mission Management Team faces potential crew and vehicle safety contingencies beyond launch and ascent. These contingencies should involve potential loss of Shuttle or crew, contain numerous uncertainties and unknowns, and require the Mission Management Team to assemble and interact with support organizations across NASA/Contractor lines and in various locations. [RTF]

Like the Shuttle Mission Management Team (MMT), the ISS Mission Management Team (IMMT) is responsible for providing programmatic oversight and management direction associated with on-orbit operations of the ISS. In response to CAIB recommendations, the ISS Program has initiated an effort to review and revise the IMMT charter and processes including the adequacy of relevant training plans. In addition, to further ensure that joint MMT/IMMT processes are integrated, the ISS Program is participating with the Space Shuttle Program in the definition of joint simulation cases and will participate fully in all on-orbit training planned for the Space Shuttle MMT.

R7.5-1 Establish an independent Technical Engineering Authority that is responsible for technical requirements and all waivers to them, and will build a disciplined, systematic approach to identifying, analyzing, and controlling hazards throughout the life cycle of the Shuttle System. The independent technical authority does the following as a minimum:

- **Develop and maintain technical standards for all Space Shuttle Program projects and elements**
- **Be the sole waiver-granting authority for all technical standards**
- **Conduct trend and risk analysis at the subsystem, system, and enterprise levels**
- **Own the failure mode, effects analysis and hazard reporting systems**
- **Conduct integrated hazard analysis**
- **Decide what is and is not an anomalous event**
- **Independently verify launch readiness**
- **Approve the provisions of the recertification program called for in Recommendation R9.1-1.**

The Technical Engineering Authority should be funded directly from NASA Headquarters, and should have no connection to or responsibility for schedule or program cost.

Prior to Space Shuttle return to flight (RTF), as called for in R9.1-1, NASA will develop a comprehensive plan with concrete milestones leading us to a revised organizational structure and improved management practices, and implementing CAIB recommendations 7.5-1 through 7.5-3. Over the next several months, NASA will report to Congress our progress on development of options and milestones. The ISS Program is a participant in this process.

NASA is committed to making the organizational changes necessary to respond to the CAIB recommendations 7.5-1 and 7.5-2. The process of implementing and institutionalizing these changes will include investigating funding paths, determining requirement ownership, identifying certification of flight readiness responsibility, and specifying responsibility within NASA's Office of Space Flight for cost, schedule, and technical issues.

R7.5-2 NASA Headquarters Office of Safety and Mission Assurance should have direct line authority over the entire Space Shuttle Program safety organization and should be independently resourced.

Response to this recommendation is consolidated in the response to R7.5-1.

R9.1-1 Prepare a detailed plan for defining, establishing, transitioning, and implementing an independent Technical Engineering Authority, independent safety program, and a reorganized Space Shuttle Integration Office as described in R7.5-1, R7.5-2, and R7.5-3. In addition, NASA should submit annual reports to Congress, as part of the budget review process, on its implementation activities. [RTF]

Response to this recommendation is consolidated in the response to R7.5-1.

R7.5-3 Reorganize the Space Shuttle Integration Office to make it capable of integrating all elements of the Space Shuttle Program, including the Orbiter.

The nature of the ISS Program has necessitated a strong focus on Program integration. As the ISS integrator, NASA has led the multilateral definition of integration processes that govern ISS design, development, operation, and utilization. NASA recognizes that this unique mix of international and organizational cultures and dependencies makes the Program integration function crucial to assuring ISS Program objectives are met, and all issues and anomalies are resolved in a timely manner.

R9.2-1 Prior to operating the Shuttle beyond 2010, develop and conduct a vehicle recertification at the material, component, subsystem, and system levels. Recertification requirements should be included in the Service Life Extension Program.

The underlying intent of this recommendation is addressed in Part 2, ISS Continuous Improvement Action ISS-7.

R10.3-1 Develop an interim program of closeout photographs for all critical sub-systems that differ from engineering drawings. Digitize the closeout photograph system so that images are immediately available for on-orbit troubleshooting. [RTF]

The nature of ISS operations dictates that careful attention is placed on closeout imagery requirements in support of complex assembly operations, as well as remote inspection and maintenance of ISS systems. Images are also used to support systems performance analyses and failure investigation. The ISS Program established requirements to obtain images from hardware as it is built up into assemblies for launch. Lessons learned while operating the ISS for almost 5 years have highlighted the importance of closeout imagery and led to strengthening of closeout imagery requirements.

Preflight imagery for International Partner modules being integrated and processed at KSC will be acquired per existing requirements. Additionally, ongoing reviews of the preflight imagery plans are performed to assure that all future modules/hardware are fully compliant with ISS Program imagery requirements. On-orbit configuration changes also include imagery closeout requirements and procedures.

R10.3-2 Provide adequate resources for a long-term program to upgrade the Shuttle engineering drawing system including:

- **Reviewing drawings for accuracy**
- **Converting all drawings to a computer-aided drafting system**
- **Incorporating engineering changes**

The nature of ISS has dictated that careful attention is placed on development, control, and rapid access to engineering data (i.e., drawings). With this in mind, the ISS Program's overall strategy from initiation has been to develop and implement an electronic drawing system. ISS drawings reside in the Vehicle Master Data Base (VMDB). The VMDB has been in operation since 1995. Portions of the VMDB in .pdf are currently scheduled (first quarter FY2004) to be integrated into a new product data management system called the ISS Electronic Document Management System. With this tool, improvement in integration of documents from different sources will be accomplished.

Response Summaries

Part 2 – ISS Continuous Improvement Actions – Other Corrective Actions

NASA accepts the *Columbia* Accident Investigation Board (CAIB) findings, will comply with the recommendations, and embraces the Report. We recognize that we must also undertake a fundamental reevaluation of our management culture and processes. To do this, we are participating in the intensive, Agency-wide effort to identify additional actions above and beyond the CAIB recommendations that will further improve the International Space Station (ISS) Program as we continue to mature. The following ISS Continuous Improvement Actions are included here to demonstrate clearly that we are not only evaluating CAIB-recognized issues, but are taking a proactive lead to identify what aspects of our processes and procedures we can do better. Part 2 will be revised in future updates to include responses to the CAIB Report Observations as well as other relevant input provided by the CAIB.

ISS-1 The ISS Program will review all Program waivers, deviations, and exceptions for validity and acceptability.

The ISS Program has directed all elements to review these exemptions to Program requirements to determine whether the exemption is still valid after nearly 5 years of on-orbit ISS operational experience. In addition, ISS Program will evaluate the exemptions to assess whether the totality of exemptions carries additional risk. Particular attention is being placed on those exemptions that carry safety risks of a catastrophic nature with a short time to effect. Unlike the Space Shuttle, the ISS vehicle does not have the requirement to safely launch its crew. For this reason, the nature of risks faced by the ISS Program are different.

The ISS Program will develop a plan to incorporate a periodic review of the waivers, deviations, and exceptions and the associated risk accepted by the Program.

ISS-2 The International Space Station Program will review all hazard report nonconformances, regardless of classification, to review rationale for acceptance of these "accepted risks."

The failure to meet ISS safety requirements constitutes a safety risk to the ISS and its crew. In each case a safety requirement is not met, a careful review of the design and its application is performed. When operational controls are considered acceptable, a nonconformance report (NCR) is generated to justify and accept the risk. As a result of the *Columbia* accident, the ISS Safety Review Panel (SRP) conducted a review of each NCR to determine whether the ISS Program should revisit the associated accepted safety risks.

ISS-3 The ISS Program will review its Certification of Flight Readiness (CoFR) process and identify areas for improvement.

The ISS Program formed a team to assess the adequacy of its Certification of Flight Readiness (CoFR) process and make recommendations for improving the way we review the risks accepted when committing to flight and continued operation of the ISS. This assessment included a process review, a documentation review, and an audit of the key processes used by certifying organizations in making their endorsement decisions. ISS Program management reviewed the initial recommendations in September 2003 and has implemented many recommendations in conduct of Soyuz Stage Operations Readiness and Flight Readiness Reviews.

ISS-4 The ISS Program has initiated a review of its critical items lists (CIL) and the failure modes and effects analyses (FMEAs) associated with the CIL to revalidate acceptance rationale based on experience gained in operating a crewed ISS for almost 3 years.

This process was successfully executed during the 7Soyuz Stage Operations Readiness Review and Flight Readiness Review as all Program elements fully discussed concerns surrounding the ISS environmental monitoring capability. When concerns with the adequacy of ISS environmental monitoring were brought to the Stage Operations Readiness Review, these concerns were openly discussed actions that were put in place to ensure that all possible steps to mitigate the risk were taken. The concerns and mitigating actions were fully discussed at the Flight Readiness Review, where NASA management decided to proceed with the launch of the Expedition 8 crew.

ISS-5 Review ISS anomaly resolution processes to ensure that proper requirements are in place and anomaly resolution processes are operating effectively.

The ISS Program evaluated the current ISS anomaly investigation and resolution requirements to determine their adequacy to support final assembly and long-term sustaining engineering of the ISS. The review resulted in several recommended actions to improve the anomaly resolution process and to ensure consistency in anomaly resolution and anomaly documentation as well as to provide ISS management useful methods by which to assess and track anomalies. Many of these recommended actions have been implemented. An action schedule has been developed and presented to ISS Program management to capture the remaining recommendations.

ISS-6 Review ISS system performance trending requirements and implementation status and make recommendations for improvement.

The monitoring of trends in the performance of the ISS is becoming increasingly important as the time of operation of its subsystems increases and its overall complexity grows. The grounding of the Shuttle fleet and potential effects on ISS resupply have heightened concern in this area. The ISS Program undertook the performance trending continuous improvement action to improve its capabilities and processes in acquiring, tracking, managing, reporting, reviewing, and using performance trending data in support of ISS planning, decision-making, and risk management.

Improvements in these areas are expected to facilitate the ISS Program's ability to detect and respond to trends or recurring events that could otherwise lead to an eventual failure or catastrophic occurrence without intervention. Performance trend data are also used for supportability planning in areas such as logistics, spares provisioning, reliability predictions, and resource management. These data can additionally be applied to help establish launch and increment readiness, and to support decisions in mission support and anomaly resolution. Performance trending is also considered to be essential for risk assessment and risk management.

ISS-7 The ISS Program will assess its hardware (ground and on orbit) to verify that it is within hardware qualification and certification limits in light of the grounding of the Space Shuttle fleet. Where life limits are approaching, appropriate action will be taken.

Some ISS hardware now awaiting launch at the Kennedy Space Center have a limited shelf life, such as the electrical power system batteries and solar array wings. A limited set of hardware on orbit is designed for periodic replacement and, therefore, carries certification limits that affect its useful life. With the grounding of the Space Shuttle fleet, the ISS Program has systematically reviewed hardware certification limits and taken the necessary actions.

The ISS Program has established on-ground preventative maintenance requirements for spare hardware that is still on the ground and is not integrated into larger elements. However, no on-ground preventative maintenance requirements exist for hardware once integrated into larger elements, such as truss sections. Launch delays due to the *Columbia* accident have driven the ISS Program to assess and define the preventative maintenance requirements for integrated hardware waiting for launch. The ISS Program is taking action to meet these requirements to gain the confidence that integrated hardware will function as required when assembled on ISS.

Within weeks of the *Columbia* tragedy, all on-orbit hardware with certification limits were reviewed. Where additional testing or analyses could be done to extend these certification limits, this testing and analysis was approved and performed. Where this was not possible, strategies and justifications were developed to allow continued use of these items in an acceptable manner.

ISS-8 Review lessons learned from ISS operations and identify any enhancements to ISS hardware or software that significantly mitigate risk to crew safety and mission success. Survey ISS system teams to identify any further modifications to hardware or software that reduce risk.

Enhancements to the ISS design are defined as changes that are over and above those which are required to meet ISS Program requirements, which significantly mitigate risk to crew safety or mission success. The ISS Program conducted a bottom-up review of potential enhancements and selected several for implementation. At the completion of the ISS enhancements review, the total list of suggested improvements has been collected and will serve as an input to the ISS Planned Product Performance Improvements (P^3I) process.

ISS-9 Review ISS Program and supporting organization contingency action plans and update them based on *Columbia* mishap lessons learned.

The ISS Program performed an extensive review of the ISS Contingency Action Plan during the March–July 2003 time frame to reflect the lessons learned from the *Columbia* mishap. International Space Station Program Office and ISS support offices/directorates personnel participated in the review and the update of this Plan. As a result of this activity, the ISS Program Manager approved the ISS Program Contingency Action Plan on July 29, 2003. NASA periodically reviews the ISS Contingency Action Plan and conducts contingency simulations to ensure that key personnel are familiar with the Contingency Action Plan.

ISS-10 The ISS Program's avionics and software management organization will continue to evolve software development and integration processes to provide high-fidelity flight software suites with higher productivity. In addition, ISS software uplink and long-term sustaining processes will be updated to reflect lessons learned from ongoing ISS software upgrade activities.

The ISS has initiated an effort to improve its software development processes. The Software Engineering Institute's (SEI) Capability Maturity Model (CMM) is being used as the "measuring stick" by which to document the maturity of each developer's processes. The ISS software development effort is following the lead of the Space Shuttle Program flight software in seeking to achieve a Level 5 assessment.

To date, over 1.25 million source lines of code have been developed and flown with minimal problems. Lessons learned from software upgrades on orbit are continually applied to improving software management processes.

ISS-11 The ISS Program has implemented some initiatives to facilitate the reporting of occupational and on-orbit safety concerns by its employees.

The ISS Program has implemented an approach to increase ISS Program employee awareness of established NASA safety reporting systems. The goal is to ensure that employees are encouraged to report any safety concerns, as well as to ensure that employees are aware of the NASA Safety Reporting System program availability. The ISS Program will continue to make personnel aware of the methods available to report safety concerns, as well as to modify the communication methods as improvements are identified.

ISS-12 The ISS Program has initiated action to make recommendations for improvements in quality assurance aspects of ISS development and operations.

The mission of ISS Program quality assurance (QA) is to ensure that the ISS Program maintains the necessary discipline in adhering to requirements and executing processes, thus contributing to overall technical excellence and the safety of the ISS vehicle and crew.

To accomplish our goals, high-quality processes must be established and effective QA activities must be in place. The ISS Program has identified the need to strengthen the QA role in several areas. A specific action is in place to accomplish this.

ISS-13 The ISS Program will assess its process for tracking Top Program Risks via the existing ISS risk management tool, specifically the Integrated Risk Management Application, and recommend improvements where necessary.

The ISS Program is reviewing all accepted, mitigated, and closed risks in the safety, quality, and reliability areas to review where significant risk (i.e., catastrophic consequences with a short time to effect) has been accepted and whether these items should be reopened and action taken to further mitigate the risk. They will also be defined as Top Program Risks and brought into the existing ISS continuous risk management process for increased visibility.

Part 1

The International Space Station's Response to the *Columbia* Accident Investigation Board's Recommendations

The following section details NASA's response to each applicable CAIB recommendation in the order that it appears in the CAIB report. This is a preliminary plan that will be updated as further actions are identified and completed. We will also update this document to include responses to the CAIB observations and other CAIB Report Volumes as they are released.

Columbia Accident Investigation Board

Recommendation 3.2-1

Initiate an aggressive program to eliminate all External Tank Thermal Protection System debris shedding at the source with particular emphasis on the region where the bipod struts attach to the External Tank. [RT]

BACKGROUND

Although this recommendation addresses threats from loose hardware generated during the launch of the Space Shuttle, the International Space Station (ISS) Program recognizes that the safety of the ISS vehicle and other visiting vehicles also depends on avoidance of threats from uncontrolled hardware.

ISS PROGRAM IMPLEMENTATION

ISS is designed to avoid debris generation by the orbital vehicle and visiting vehicles (Soyuz, Progress, Automated Transfer Vehicle, H-II Transfer Vehicle). Requirements, such as SSP-30426, Space Station External Communication Control Requirements, impose limits upon generation of external contaminants. SSP-50235, Interface Definition Document for International Space Station Visiting Vehicles, includes Applicable Requirements for visiting vehicles.

Operational steps are taken to preclude threats associated with potential debris sources. Prior to launch, technicians and quality personnel conduct inspections to eliminate any foreign object debris from ISS cargo prior to launch. Closeout imagery records the general level of compliance and aids troubleshooting. Flight rules, procedures, and training do not permit the jettison of solid materials into space in proximity of ISS. Overboard dumping of wastes is minimized.

ISS also has operational controls that reduce the risks of impacts between ISS elements. For example, robotic and extravehicular activity crew maneuvers are analyzed, trained, and performed with care to prevent hazardous contacts. Visiting vehicle activities are choreographed to minimize docking port relocations and improper contact.

Periodic recorded imagery from visiting vehicles and external cameras helps to verify the current safe condition of the ISS exterior. Ground-based radar tracking reported to NASA by the U.S. Air Force provides additional useful information on orbital debris threats.

STATUS

Existing risk mitigation measures are in place to control and assess this potential hazard. ISS Program management, design engineers, crew members, flight controllers, training instructors, and safety teams continue to provide assurance of this risk mitigation.

Lessons learned from near misses during early assembly activities have driven increased use of tools to model the current position of external hardware and increased focus on the importance of operational controls.

FORWARD WORK

Continued diligence in the use of design and operational controls.

SCHEDULE

Ongoing.

Columbia Accident Investigation Board

Recommendation 3.3-2

Initiate a program designed to increase the Orbiter’s ability to sustain minor debris damage by measures such as improved impact-resistant Reinforced Carbon-Carbon and acreage tiles. This program should determine the actual impact resistance of current materials and the effect of likely debris strikes. [RTF]

The underlying intent of this recommendation is addressed by Part 2, ISS Continuous Improvement Action ISS-8.

Columbia Accident Investigation Board

Recommendation 3.3-1

Develop and implement a comprehensive inspection plan to determine the structural integrity of all Reinforced Carbon-Carbon system components. This inspection plan should take advantage of advanced non-destructive inspection technology. [RTF]

The underlying intent of this recommendation is addressed in Part 1, R4.2-4.

Columbia Accident Investigation Board

Recommendation 6.4-1

For missions to the International Space Station, develop a practicable capability to inspect and effect emergency repairs to the widest possible range of damage to the Thermal Protection System, including both tile and Reinforced Carbon-Carbon, taking advantage of the additional capabilities available when near to or docked at the International Space Station.

For non-Station missions, develop a comprehensive autonomous (independent of Station) inspection and repair capability to cover the widest possible range of damage scenarios.

Accomplish an on-orbit Thermal Protection System inspection, using appropriate assets and capabilities, early in all missions.

The ultimate objective should be a fully autonomous capability for all missions to address the possibility that an International Space Station mission fails to achieve the correct orbit, fails to dock successfully, or is damaged during or after undocking. [RTF]

BACKGROUND

The International Space Station (ISS) Program is working with the Space Shuttle Program to develop a method to inspect and effect emergency repairs to the Space Shuttle Thermal Protection System. These efforts are documented in Volume 1 of NASA's Implementation Plan for Space Shuttle Return to Flight and Beyond, reference sections 6.4-1 and SSP-3.

The ISS Program has extensive, existing visual inspection capabilities and instrumentation to determine the health of its vehicle. To meet the intent of this recommendation, the ISS inspection requirements and implementation details were examined to assess their adequacy.

Additionally, ISS has on-board maintenance and repair capabilities that help to ensure vehicle and crew safety. This includes on-board spare, tools, and repair procedures.

ISS PROGRAM IMPLEMENTATION

Inspection requirements for internal ISS systems and external ISS systems were reviewed. Internal systems inspection requirements were found to be adequately documented and the requirements satisfactorily implemented. External ISS systems inspection requirements relied heavily on photos taken by a visiting/departing Space Shuttle. Implementation without the Shuttle was found to be inadequate. In response to this situation, the ISS Program has developed a systematic approach for performing an exterior imagery survey by on-board assets.

The ISS Program has instituted a plan to periodically perform these external surveys. On-board assets provide viewing capability for a significant portion of the vehicle exterior. However, some surfaces cannot be viewed with on-board assets alone, as shown in Figure 6.4-1.1. Viewing these areas requires imagery supplied by remote assets, extravehicular activity (EVA) or visiting vehicles. Note that Figure 6.4-1.1 assumptions include fully functional ISS robotic and camera systems.

The external survey supports hardware configuration verification, assessment of material degradation, and identification of visible anomalies; it also provides a historical set of images to assess the long-term progression of degradation and facilitate future problem resolution. Under the leadership of the ISS Mission Evaluation Room, a team was established to identify specific external survey imagery requirements; collect, store, and disseminate the imagery; review collected imagery; report their findings; and lead follow-up investigation of potential anomalies when indicated.

The imagery team developed a plan to obtain the necessary images from truss-mounted cameras, robotic system cameras, and crew views through ISS module windows. For imagery taken by the crew, the team identified video quality requirements that can be satisfied with cameras on board ISS.

Dedicated external surveys are also augmented by imagery collected during EVA. During EVA, helmet camera video and still imagery are typically used as assembly closeout documentation and to augment crew member descriptions of the anomalies they observe.

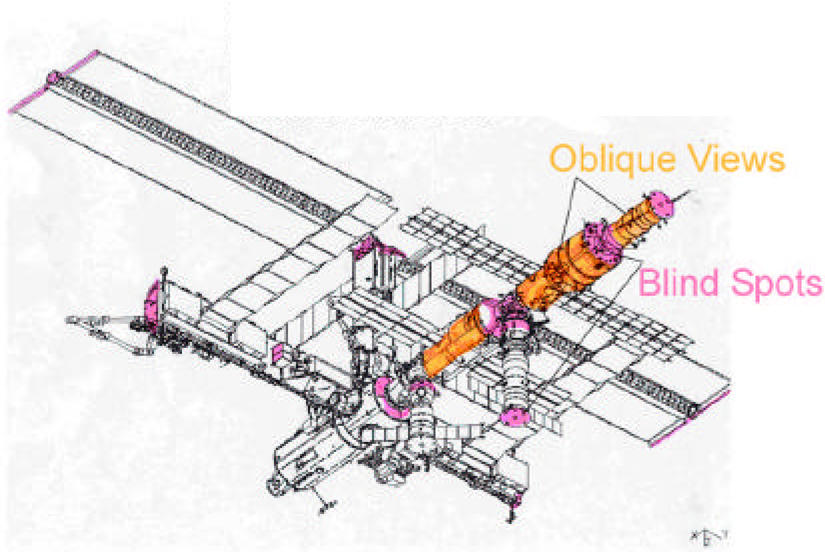


Figure 6.4-1.1. ISS external surface views that are limited when using on-board assets.

STATUS

The ISS external survey using external cameras is complete. The imagery is available in the ISS Digital Imagery Management System.

A team composed of experts representing each subsystem, the external environment, and Kennedy Space Center reviewed the imagery. The results indicate that ISS exterior hardware is generally performing as expected. In addition, several thermal blankets were scrutinized for proper configuration, and previously undetected discoloration was observed on a heat-rejection system radiator. As expected, external contamination or degradation was noted on several surfaces. No significant anomalies have yet been revealed by the initial survey.

FORWARD WORK

The remainder of the exterior survey, using robotic assets and crew observation, must be completed and analyzed, and the results reported. It is anticipated that these inspections will be performed by April 2004. In addition, the frequency at which the survey (or portions of the survey) is performed will be established and adjusted based on the survey findings.

New ISS modules will provide further vantage points through windows for external surveys of ISS surfaces and systems. Furthermore, two additional external video cameras will be installed on truss segments, thereby increasing the external mapping capability. The future robotic arm enhancement—the Special Purpose Dexterous Manipulator, built by Canada—will have built-in video cameras that can be used for detailed inspections.

NASA is currently certifying EVA digital still cameras to be deployed by return to flight. These cameras could be used to obtain high-resolution imagery that can be downlinked after EVA for analysis and can be used to inspect areas that cannot be viewed by external video cameras or through ISS windows.

As in the past, upon return to flight Shuttle imagery assets will be used to survey ISS external surfaces. Orbiter-based imagery provides views of ISS external surfaces that are not visible from ISS assets and supplies additional views of areas from different perspectives.

The Soyuz vehicles docked to the ISS are inspected to the extent possible. The ISS Program, in coordination with our International Partners, will evaluate the need for additional requirements in support of external inspection of the Soyuz vehicle.

SCHEDULE

Due Date	Activity/Deliverable
Apr 2004	Complete exterior survey
Under review	Define frequency of future surveys

Columbia Accident Investigation Board

Recommendation 3.3-3

To the extent possible, increase the Orbiter's ability to successfully re-enter the Earth's atmosphere with minor leading edge structural sub-system damage.

The underlying intent of this recommendation is addressed in Part 1, R4.2-4.

Columbia Accident Investigation Board

Recommendation 3.3-4

In order to understand the true material characteristics of Reinforced Carbon-Carbon components, develop a comprehensive database of flown Reinforced Carbon-Carbon material characteristics by destructive testing and evaluation.

The underlying intent of this recommendation is addressed in Part 1, R4.2-4.

Columbia Accident Investigation Board

Recommendation 3.3-5

Improve the maintenance of launch pad structures to minimize the leaching of zinc primer onto Reinforced Carbon-Carbon components.

This recommendation is not applicable to the ISS.

Columbia Accident Investigation Board

Recommendation 3.8-1

Obtain sufficient spare Reinforced Carbon-Carbon panel assemblies and associated support components to ensure that decisions related to Reinforced Carbon-Carbon maintenance are made on the basis of component specifications, free of external pressures relating to schedules, costs, or other considerations.

BACKGROUND

The International Space Station (ISS) has no Reinforced Carbon-Carbon panels; however, there are a number of systems that are required to provide life support and sustain operations. Focusing on the importance of spares to minimize decisions that would be subject to schedule pressure, the ISS Program reviewed its spares provision plans and processes for adequacy. The ISS Program plans and processes were determined to be adequate.

After the Shuttle accident and in response to the *Columbia* Accident Investigation Board recommendations, the ISS Program has reviewed its logistics and maintenance plans to ensure that sparing plans are adjusted for the extended Space Shuttle downtime. This process continues as the downtime is extended and critical decisions affecting spares must be made. A spare is currently pre-positioned on orbit for many of these critical orbital replaceable units (ORUs). Since the loss of *Columbia*, Progress and Soyuz capacity has limited the ability to deliver limited-life items and large ORUs.

ISS PROGRAM IMPLEMENTATION

The ISS Program uses a combination of simulation analysis and in-depth technical understanding to determine sparing for the ISS. Functional availability is the chief criteria used to determine adequacy of sparing. This methodology uses a predictive measure to assess the continuous on-orbit operation of ISS. Availability is defined as the percentage of time that an ORU or a function is operating. Key data and assumptions for functional availability include reliability data, spares quantities and locations, repair times, redundancy, manifest limitations (flights per year, cargo capability), crew limitations, and on-orbit stowage locations. Reliability data include items such as mean time between failures (MTBF), duty cycle, induced failure factor, and condemnation rates.

ORU data were obtained from the ISS Prime contractor Boeing and its vendors to understand the hardware and failure impacts. Special attention was placed on hardware performing a critical function to ensure that the proper number of spares is procured.

The ISS Program analyzed the potential for critical failures at each stage of assembly. For anticipated failures that could currently threaten loss of the ISS or cause the crew to evacuate, spares are in place or redundancy is sufficient to accommodate failures. Plans are in place to cover future ISS configurations.

STATUS

Due to the Shuttle fleet being grounded, the ISS Program has reassessed the on-orbit and resupply approach. Currently, the Russian Progress and Soyuz launch vehicles are the only means of delivering spares to orbit. With few exceptions, the Progress vehicle meets all demands for the Space Station to be able to sustain its internal hardware; however, the Progress vehicle cannot return hardware to ground for repair. A limited number of small items are being returned on Soyuz. Some external hardware cannot be launched to orbit on Russian vehicles, but the majority of critical spares are currently on orbit. All required preventive maintenance ORUs can be resupplied on Progress. Additionally, all of the external ORUs are currently operating satisfactorily.

With current manifest constraints, the ISS Program is assessing workarounds to ensure that the necessary spares and items are delivered to orbit. The ISS Program is also implementing actions to reduce the need to launch additional equipment. For example, the crew is using kits to refurbish hardware on orbit, when possible. For some items, specially designed preventative maintenance tasks are being performed to extend hardware lifetime.

FORWARD WORK

The ISS Program will continue activities to lessen dependence on Shuttle resupply. We are continuing to evaluate on-orbit repair of some ORUs rather than replacement to make best use of limited resupply.

SCHEDULE

Due Date	Activity/Deliverable
Continuous	Develop and implement plans to keep ISS hardware operational with no Shuttle resupply

Columbia Accident Investigation Board

Recommendation 3.8-2

Develop, validate, and maintain physics-based computer models to evaluate Thermal Protection System damage from debris impacts. These tools should provide realistic and timely estimates of any impact damage from possible debris from any source that may ultimately impact the Orbiter. Establish impact damage thresholds that trigger responsive corrective action, such as on-orbit inspection and repair, when indicated.

BACKGROUND

While the *Columbia* Accident Investigation Board's (CAIB's) action was specific to the debris impacts on a Shuttle, the International Space Station (ISS) Program initiated steps to assess all of the ISS analytical models and tools that are used to support on-orbit operations, anomaly resolution, and decision-making processes. ISS Program boards are reviewing the models to ensure that the model basis, assumptions, limitations, and boundary conditions are understood and acceptable. The ISS Program boards will address any identified augmentations required as the result of their assessment.

ISS PROGRAM IMPLEMENTATION

The ISS Program is in the process of assessing all of the analytical models and tools used in mission support. The models included are those used during hardware development and verification, those developed to support on-orbit vehicle nominal operations, those used for flight rule or procedure development, and those developed to support resolution of on-orbit anomalies. Assessments will determine the adequacy of the current level of correlation, verification and validation, and configuration management for ISS models and tools. Assessment will ensure that system performance models are physics based, as appropriate.

As pointed out in the CAIB Report, "engineering solutions presented to management should have included a quantifiable range of uncertainty and risk analysis." In response to this finding, the ISS Program will develop processes to ensure that conservatism and uncertainty associated with critical analyses are thoroughly and consistently communicated to Program management. The ISS Program has hosted a short course on "Experimentation and Uncertainty Analysis" for analysts and managers involved in mission support.

In addition to the assessment of models and tools used for mission support, a presentation template has been developed as an aid for presenting analytical data to ISS Program boards or anomaly resolution teams. The presentation format includes specific information on models including the model verification and validation history, uncertainty factors, and conservatism. The intent of the template is to facilitate the communication between the analysts and decision makers so that the key assumptions bounding the analyses and the results are understood in terms of associated risk and potential consequences.

STATUS

The review of ISS models and tools is under way. The ISS Mission Evaluation Room has implemented the data presentation template for its technical reports to the ISS Mission Management Team. Uncertainty Analysis techniques are under development, and analysts and managers involved in mission support have completed a short course on "Experimental and Uncertainty Analysis."

FORWARD WORK

As assessments get completed on models and tools, recommendations on areas that need to be improved will be identified and brought to the Space Station Program Control Board for approval. In addition, ISS subsystem teams will address areas of known analytical weakness (model correlation to on-orbit data, additional space flight tests, etc.) to determine if past decisions were made with full knowledge of the associated risk regarding the pedigree of the analytical models and tools used. Uncertainty analysis techniques for ISS applications will continue to be developed and will be reviewed by ISS management for implementation by subsystem teams.

SCHEDULE

Due Date	Activity/Deliverable
August 2003	Completed training on uncertainty analysis
Under review	Complete model and tool assessments

Columbia Accident Investigation Board

Recommendation 3.4-1

Upgrade the imaging system to be capable of providing a minimum of three useful views of the Space Shuttle from liftoff to at least Solid Rocket Booster separation, along any expected ascent azimuth. The operational status of these assets should be included in the Launch Commit Criteria for future launches. Consider using ships or aircraft to provide additional views of the Shuttle during ascent. [RTF]

The underlying intent of this recommendation is addressed in Part 1, R6.3-2 and R6.4-1.

Columbia Accident Investigation Board

Recommendation 3.4-2

Provide a capability to obtain and downlink high-resolution images of the External Tank after it separates. [RTF]

The underlying intent of this recommendation is addressed in Part 1, R6.3-2 and R6.4-1.

Columbia Accident Investigation Board

Recommendation 3.4-3

Provide a capability to obtain and downlink high-resolution images of the underside of the Orbiter wing leading edge and forward section of both wings' Thermal Protection System. [RTF]

The underlying intent of this recommendation is addressed in Part 1, R6.3-2 and R6.4-1.

Columbia Accident Investigation Board

Recommendation 6.3-2

Modify the Memorandum of Agreement with the National Imagery and Mapping Agency (NIMA) to make the imaging of each Shuttle flight while on orbit a standard requirement [RTF].

BACKGROUND

The International Space Station (ISS) Program will take advantage of national assets to support on-orbit assessment of the ISS external condition.

ISS PROGRAM IMPLEMENTATION

NASA has already concluded a Memorandum of Agreement with the National Imagery and Mapping Agency that provides for on-orbit assessment, which includes ISS support. In addition, NASA has initiated discussions across the interagency community to explore the use of appropriate national assets to evaluate the condition of the Orbiter vehicle and ISS.

Since this action may involve receipt and handling of classified information, the appropriate security safeguards will be observed during its implementation.

STATUS

The ISS Program has determined which positions/ personnel will require access to data obtained from external sources. The ISS Program will ensure that appropriate personnel are familiar with the general capabilities available for on-orbit assessment and that appropriate personnel are familiar with the means to gain access to that information.

The ISS Program has already begun the process to obtain the required clearances.

FORWARD WORK

The operational teams will develop standard operating procedures to implement any agreements with the appropriate government agencies.

An internal NASA process is being used to track clearances and training of personnel.

SCHEDULE

Due Date	Activity/Deliverable
Under review	Complete initial plan for personnel training
Under review	Complete initial ISS operational procedures

Columbia Accident Investigation Board

Recommendation 3.6-1

The Modular Auxiliary Data System instrumentation and sensor suite on each Orbiter should be maintained and updated to include current sensor and data acquisition technologies.

Recommendation 3.6-2

The Modular Auxiliary Data System should be redesigned to include engineering performance and vehicle health information, and have the ability to be reconfigured during flight in order to allow certain data to be recorded, telemetered, or both, as needs change.

BACKGROUND

The Modular Auxiliary Data System (MADS), which is also referred to in the *Columbia* Accident Investigation Report as the “OEX recorder,” is an Orbiter recorder for collecting engineering performance data. MADS records data on the environment experienced by and the responses of the Orbiter during ascent and entry.

Although the International Space Station (ISS) does not use a MADS recorder, the ISS still depends on telemetry for engineering performance data. Because the ISS does not return to the ground for processing, most performance data are downlinked from orbit.

ISS PROGRAM IMPLEMENTATION

Engineering performance data are required through the life of the ISS.

The S-band telemetry from ISS shares bandwidth with two channels of compressed audio. Data exchange with the ground is via the tracking and data relay satellite in geosynchronous orbit. All of the available telemetry bandwidth of the S-band has been fully subscribed since the U.S. Laboratory module was deployed in 2001.

ISS Program requirements control what data are downlinked. These requirements include vehicle performance assessment as well as real-time operational assessment. All telemetry users have the opportunity to submit requirements to this process. When requirements exceed downlink bandwidth capability, multiple telemetry formats are established to facilitate sharing.

As individual required sensors fail or become unreliable, the ISS Program replaces the sensor, recalibrates the sensor, or identifies an alternate approach to gathering the information. As new instrumentation needs are identified, add-on capabilities are procured.

Planned Product Performance Improvements (P^3I) to the ISS avionics will address upgrades to engineering performance data capabilities and are focused at increasing the bandwidth for telemetry.

STATUS

The ISS Program and the Mission Operations Directorate have identified no risks to sustained operation of the ISS due to deficient instrumentation.

Systems that perform functions much like the sensor suite and recorders of the MADS were defined as formal ISS requirements and implemented as part of the basic Program and are to be maintained for the life of the Program. The equivalent to the MADS is the Structural Dynamic Measurement System. That system comprises 33 accelerometers, 38 strain gauge bridges, two signal conditioners, connecting wires, and software. The accelerometers are mounted on all truss segments without solar arrays. The strain gauges are mounted on the critical rotating equipment. The signal conditioning units boost measurement inputs and record and buffer the data so the data can be sent to the ground.

The ISS Program identified additional requirements for structural measurements and environmental characterization after the initial design of ISS. In each case, innovative solutions were accommodated without the addition of new cabling. The first of these new requirements measures structural strains and accelerations in the pressurized volume to characterize dynamic response. Internal wireless instrumentation was developed to implement this capability. The second of the new requirements measures the voltage potential of the ISS compared to the ambient plasma as well as the ionospheric plasma electron density and electron temperature. The Floating Potential Measurement Unit measures the existence and severity of spacecraft charging hazards. Real data on spacecraft charging characteristics permit hazard control strategies that minimize overall risk to the vehicle and crew.

To increase bandwidth for sending telemetry to the ground, two approved enhancements are in work. One will upgrade the ISS computers to increase their data processing and storage capability and to make all the data available for Ku-band downlink. This upgrade will allow all ISS telemetry to be downlinked continuously. The second enhancement will increase the bandwidth of the Ku-band data stream to the ground from 50 megabits per second to 150 megabits per second. The change also increases data transmission from the ground station at White Sands, New Mexico, to Houston and Huntsville. The conceptual design and testing of this upgrade is under way.

FORWARD WORK

Implementation of upgrades to computer and Ku-band systems for increased downlink bandwidth.

Future assessments through P^3I.

SCHEDULE

For the computer upgrade:

Due Date	Activity/Deliverable
Jun 2004	Preliminary Design Review
Dec 2004	Detailed Design Review
Dec 2005	Delivery of first flight unit

For the Ku-band upgrade:

Due Date	Activity/Deliverable
Dec 2003	Replace satellite link between White Sands and other NASA centers with fiber optic cable
Dec 2005	Full 150 megabits per second

Columbia Accident Investigation Board

Recommendation 4.2-2

As part of the Shuttle Service Life Extension Program and potential 40-year service life, develop a state-of-the-art means to inspect all Orbiter wiring, including that which is inaccessible.

BACKGROUND

The nature of the International Space Station (ISS) system dictates that physical wiring inspections be performed on orbit. Once operational, the environment that ISS wiring is exposed to is limited to conditions on orbit. Internal wiring is susceptible to damage when it, or hardware nearby, is manipulated through normal daily activity on the ISS. Plans are in place to perform routine wiring “inspections of opportunity” in high traffic areas as part of the normal ISS systems maintenance. External wiring was designed to operate in the micrometeoroid and orbital debris environment of low Earth orbit.

Even though the ISS elements on orbit have only been in place for up to 5 years, the ISS Program will evaluate whether additional routine wiring inspections should be implemented in response to aging effects.

ISS PROGRAM IMPLEMENTATION

ISS is designed to have redundancy in critical systems. If an unnoticed wiring problem causes a failure of a critical system, redundant systems can provide the critical function.

While the crew has not been provided with standard criteria by which to evaluate a wiring condition nor are there requirements for routine wiring inspections outside of maintenance activities, other means are used to control this risk. ISS crew members are trained to report hardware conditions that are out of the ordinary. When the crew is working in an area that has exposed wires, they report to the ground any time they see fraying or chafing of wires. Crew inspections have resulted in the ground being notified of wiring issues before the wiring problems induced problems with associated hardware. For example, at one point, the Service Module food warmer displayed signs of degradation of the protective covering of some wiring. Because the crew members were trained to look for this type of anomalous situation, they reported the degradation to the ground and corrective action was taken before any systems anomaly occurred.

Additionally, one function of the Mission Evaluation Review team in the Mission Control Center is to review all telemetry data from the ISS for anomalous signatures. Any anomalous signatures are investigated and, where wiring is a possible cause, inspections are given consideration by the anomaly resolution team.

STATUS

The ISS Program has determined that its two-pronged inspection technique is sufficient for this phase of the ISS Program. These techniques can be summarized as:

1. Performing “inspections of opportunity” when wiring is exposed through normal daily activity or scheduled maintenance.
2. Relying on anomalous hardware signatures from the ISS detected on the ground from telemetry.

FORWARD WORK

The ISS Program will evaluate whether or not the ISS crews need to be trained to evaluate wiring against specific criteria and/or include wiring inspection criteria within maintenance procedures.

The ISS Program will also assess the risks of wiring aging through the whole vehicle life. In this case, the ISS Program will evaluate whether routine wiring inspections should be implemented and if state-of-the-art technology is needed to aid inspections.

SCHEDULE

Due Date	Activity/Deliverable
Under review	Assess wiring aging risks and recommend needed actions

Columbia Accident Investigation Board

Recommendation 4.2-1

Test and qualify the flight hardware bolt catchers. [RTF]

The underlying intent of this recommendation is addressed in Part 2, ISS Continuous Improvement Action ISS-12.

Columbia Accident Investigation Board

Recommendation 4.2-3

Require that at least two employees attend all final closeouts and intertank area hand-spraying procedures. [RTF]

BACKGROUND

External Tank final closeouts and intertank area hand-spraying processes typically require more than one person in attendance to execute procedures. Although those close-out processes currently performed by a single person did not necessarily specify an independent witness or verification, that is not the case for International Space Station (ISS) closeouts. For ISS, standard processing practices at Kennedy Space Center (KSC) require independent witness verification.

ISS PROGRAM IMPLEMENTATION

ISS procedures at KSC were reviewed to confirm that requirements are adequately defined and implemented. In concert with ISS Program requirements, the ISS closeout procedures are documented in Boeing Standard Practice SP-QUAL-002, ISS Configured for Test and Flight. The rigorous two-step process to flight closeouts is described in this Boeing document and applies to ISS Prime contractor operations. NASA/ISS Program personnel and the Checkout Assembly and Payload Processing contractor currently close out areas with Work Authorization Documents (WADs) that require both NASA and Boeing quality assurance stamps. These guidelines are being formulated into a Standard Practice and Procedure that will apply to all ISS Program hardware processed at KSC.

The ISS Program has strict guidelines for what will be documented in the WAD, including assurance that closeout photos are taken and that both government and contractor quality assurance personnel accept the area. If changes to closeouts are required, a new WAD is created referencing the previous closeout WAD. At a minimum, Boeing Engineering and Boeing and government Quality Assurance are mandatory witnesses; and these personnel will determine if Materials and Processing Engineering, Flight Crew representatives, and Thermal Engineering are also required. Any rework will automatically require closeout photography. ISS closeout imagery is further discussed in response to R3.4-1, R10.3-1, and R6.4-1.

STATUS

Existing ISS procedures for processing Boeing hardware have been reviewed and determined to meet the *Columbia* Accident Investigation Board recommendation for quality control of critical procedures. These guidelines are being formulated into a Standard Practice and Procedure that will apply to all ISS Program hardware processed at KSC.

FORWARD WORK

Complete documentation to extend the guidelines to all ISS Program hardware processed at KSC.

SCHEDULE

Due Date	Activity/Deliverable
Nov 2003	Complete KSC Standard Practice and Procedure for all ISS hardware processed at KSC

Columbia Accident Investigation Board

Recommendation 4.2-4

Require the Space Shuttle to be operated with the same degree of safety for micrometeoroid and orbital debris as the degree of safety calculated for the International Space Station. Change the micrometeoroid and orbital debris safety criteria from guidelines to requirements.

BACKGROUND

Micrometeoroid and orbital debris (MMOD) is recognized as a continuing concern for the International Space Station (ISS), the Shuttle, and other spacecraft. The current differences between the ISS and Shuttle risk for critical damage from MMOD are based on the original design specification for each vehicle. The ISS was designed for long-term exposure to both micrometeoroids and orbital debris, whereas the original Shuttle design specification was to provide short-term protection from micrometeoroids only because there was not any recognized threat from orbital debris until the late 1980s (i.e., well after Shuttle design was completed). To meet ISS requirements, robust shielding protection and operational procedures are in place, or will be implemented during upcoming assembly missions, to reduce the risk of MMOD-induced threats to the crew and vehicle. In addition, ISS hardware is designed to allow MMOD shielding to be augmented over the life of the Program.

ISS PROGRAM IMPLEMENTATION

The ISS Program has implemented a three-pronged approach to reducing risks to the vehicle and crew from MMOD on ISS:

1. Implementing robust meteoroid/orbital debris shielding on the habitable modules where the crew live and work, as well as on all external propellant tanks, pressurized vessels, and control moment gyroscopes.
2. Performing collision avoidance maneuvers during ISS operations to prevent impact from all orbital debris that can be tracked from the ground.
3. Developing contingency procedures and risk mitigation techniques to deal appropriately in the event an MMOD impact causes a leak in the pressure shell of the habitable modules. For instance, sensors are on board to detect a leak, handheld tools have been developed to locate a leak internally, patch kits are available to seal a leak from inside the ISS modules, and crew training and ground operational procedures are in place to react properly to a depressurization event (i.e., detect, locate, and isolate leaks, or evacuate the ISS if warranted).

The MMOD shields on ISS are the most capable shields ever developed and flown on a spacecraft. An example of the shielding used to protect the U.S., Japanese, and European habitable modules is given in Figure 4.2-4-1. These shields measure 4 inches to 6 inches from inside to outside; and they consist of multiple layers of aluminum, ceramic cloth, and ballistic protection fabrics ("bullet-proof" materials). The Russian-provided *Zarya* Functional Energy Block (FGB) Module is protected by different shielding configurations but with similar protection capability as the U.S. shielding. The approach to *Zvezda* Service Module (SM) shielding is to launch with minimal shielding and outfit the module with "augmented" shielding on orbit by extravehicular activity. SM shield augmentation has begun, with some augmentation shields in place and others to be added soon after Shuttle return to flight. Figure 4.2-4-2 illustrates SM augmentation shields. In addition, NASA and our Russian Partners are developing plans to enhance MMOD protection of Soyuz and Progress vehicles. Hypervelocity impact tests and analyses have been performed that demonstrate significant reductions in MMOD risk for these vehicles (by a factor of five) by adding approximately 25 kg of additional shielding on the ground.

An international group led by the ISS Program is coordinating plans for development of improvements to the leak detection and repair capabilities. This includes both internal and externally applied solutions.

STATUS

MMOD shielding design and implementation is completed for FGB, Node 1, Pressurized Mating Adapters, U.S. Laboratory Module, Airlock, control moment gyros, and external pressurized tanks.

Final shield testing, evaluation, and verification is ongoing for hardware to be delivered to the ISS in future, including Node 2, cupola, Centrifuge Accommodation Module, and European and Japanese laboratories.

Augmentation of SM shielding is under way. Efforts are also under way to expedite implementation of enhanced MMOD protection for Progress and Soyuz vehicles.

The ISS Program is evaluating short-term operational methods to reduce risks of MMOD impacts, including closing hatches to the Progress and the Russian Docking Compartment when possible.

As part of the effort to identify and trend actual MMOD impact effects on ISS, NASA has implemented regular inspections of all ISS windows and other external surfaces, such as the large radiators and other truss structures. ISS is also using Shuttle-returned modules to study representative MMOD effects and mitigation performance.

FORWARD WORK

NASA is working with our Russian Partners to expeditiously implement augmented shielding for SM and enhanced protection for Progress and Soyuz. Current planning for expedited MMOD shielding calls for SM augmentation shielding to be delivered on ISS Flights 13A.1 and UF-4 or UF-4.1. Soyuz MMOD enhancement could be available as early as Flight 9S, and Progress protection enhancement may be available as early as Flight 13P.

SCHEDULE

Due Date	Activity/Deliverable
In work	Continue MMOD shielding assessments for U.S. elements
Under review	Coordinate with Russian Partners on MMOD shielding

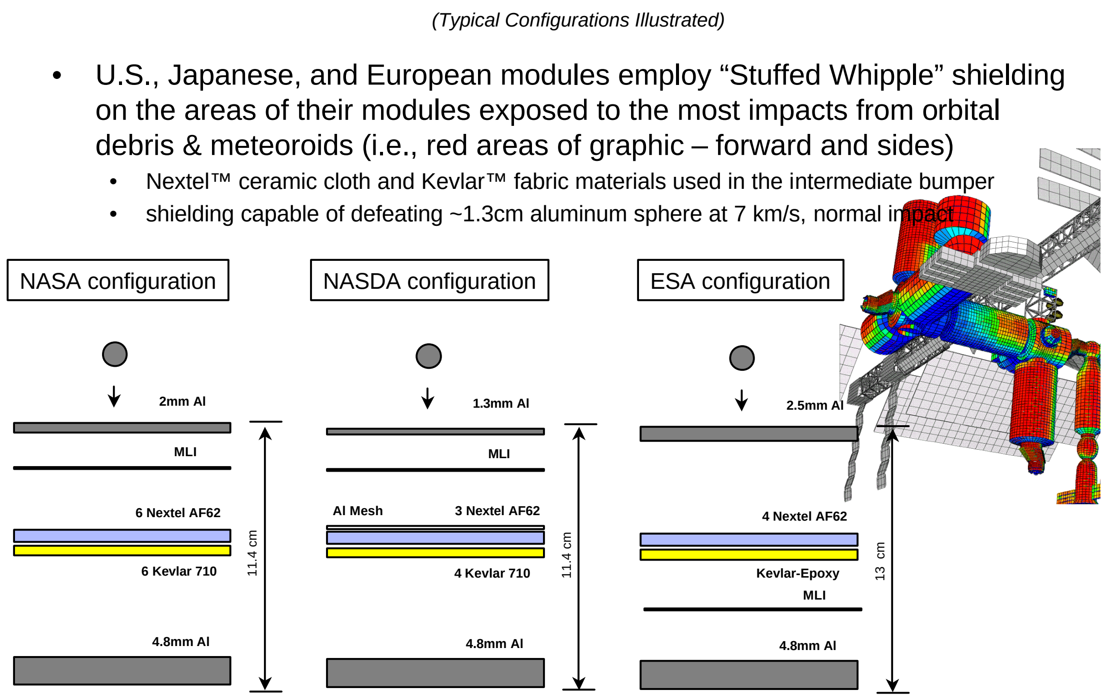


Figure 4.2-4-1. Typical MMOD shielding configurations for U.S., European, and Japanese modules.

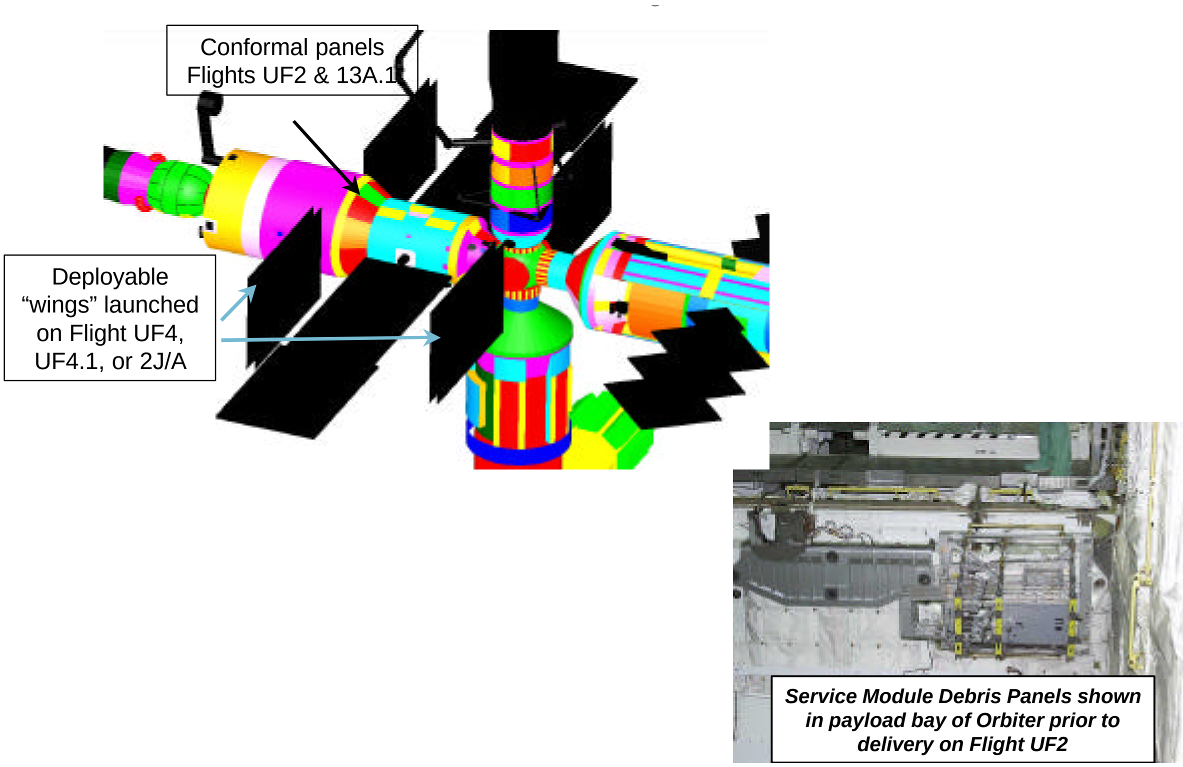


Figure 4.2-4-2. Russian Service Module augmentation shields.

Columbia Accident Investigation Board

Recommendation 4.2-5

Kennedy Space Center Quality Assurance and United Space Alliance must return to the straightforward, industry-standard definition of “Foreign Object Debris,” and eliminate any alternate or statistically deceptive definitions like “processing debris.” [RTF]

BACKGROUND

In 2001, Kennedy Space Center (KSC) Shuttle Processing recategorized foreign object debris (FOD) into two categories, “processing debris” and “FOD.” FOD was defined as debris found during the final or flight-closeout inspection process. All other debris was labeled processing debris. The categorization and subsequent use of two different definitions of debris led to a perception that processing debris was not a concern. The International Space Station (ISS) Program assessed how FOD was treated within ISS facilities.

ISS PROGRAM IMPLEMENTATION

KSC’s history of successful processing and launching of contamination-sensitive hardware is proof of an effective FOD program. Nevertheless, an independent assessment has been completed that resulted in several recommendations for improvements to this FOD program.

As the responsible contractor for payload processing at KSC, the Checkout Assembly and Payload Processing Services contractor maintains all elements of a formal FOD program, including identification, prevention, control, and correction. Responsibilities exclude metrics and trend analysis. For ISS hardware, the contractor is bound to specific ISS Program cleanliness requirements such as Space Station Requirements for Materials and Processes (SSP 32233) and Space Station External Communication Control Requirements (SSP 30426). These requirements flow down to local Standard Practices and Procedures (SPP) cleanliness requirements such as Payload Processing Work Area Rules (SPP O-01) and KSC Payload Facility Contamination Control Requirements Plan (K-STSM-14.2.1). These standards maintain the proper policy and procedures that address FOD and contamination prevention, control, and correction. Specific areas addressed in these standards include work area surveillance and rules, FOD barriers, roles and responsibilities, tool controls, garments and gowning, equipment and material controls, access controls, walkdowns and inspections, ingress and egress monitoring, employee awareness, and training.

Even though a robust contamination control process is already in place, KSC ISS engineers will evaluate the consistency of this process with Shuttle FOD Control Plans under development and evaluate possible additions of metrics and trend analysis.

Since the ISS elements and payload carriers eventually become integrated into the Shuttle payload bay before launch, it is logical to define, measure, and manage FOD produced during payload ground operations with processes, standards, and procedures similar to the Shuttle vehicle. ISS Material and Processes (M&P) engineers will work closely with Shuttle engineers to adopt one definition of FOD.

STATUS

Currently, the ISS Program M&P engineers are evaluating whether Program-level requirements documents need to be changed to standard FOD definitions with the Shuttle Program, and whether metrics and trend analysis should be required.

KSC ISS engineers and managers are working with their Shuttle counterparts and are reviewing applicable SPPs and other standards as they evaluate a potential need for a formal FOD Control Plan. Working closely with Shuttle engineers will ensure a consistent universal approach to minimize the risk of FOD to flight operations and ISS performance.

An element of the ISS currently undergoing processing for launch was recently detected to contain an excess amount of FOD. The element, Node 2, is undergoing final prelaunch checkouts. As a result of the finding of FOD in Node 2, the processing flow has been adjusted to allow engineers the opportunity to remove the FOD prior to Node 2 launch.

FORWARD WORK

KSC ISS engineers will remain in lockstep with both ISS and Shuttle Programs as they document a formal FOD

Control Plan that will include a universal definition of FOD.

ISS assembly elements, logistical carriers, and science experiments come from many different developers; i.e., NASA, International Partners, ISS contractors, vendors, commercial science entities, and academia. NASA will levy FOD requirements on each of these hardware developers to ensure a consistent and effective approach to FOD control.

SCHEDULE

Due Date	Activity/Deliverable
In work	Continue assessment of FOD program

Columbia Accident Investigation Board

Recommendation R6.2-1

Adopt and maintain a Shuttle flight schedule that is consistent with available resources. Although schedule deadlines are an important management tool, those deadlines must be regularly evaluated to ensure that any additional risk incurred to meet the schedule is recognized, understood, and acceptable. [RTF]

BACKGROUND

Schedules are integral parts of program management and provide for the integration and optimization of resource investments across a wide range of connected systems. The International Space Station (ISS) Program is just such a system, and it needs to have a visible schedule with clear milestones to effectively achieve its mission. The ISS Program will not compromise system safety in our effort to optimize schedules. All activities are associated with very specific milestones that must be completed for mission success. If these milestones can be accomplished safely, the scheduled activities occur on time. If a milestone is not accomplished, the schedules are extended consistent with the need for safety. ISS Program management requires greater insight into Program status than that provided by schedules alone. ISS has implemented a suite of Program control tools and processes to monitor schedule-budget compatibility, elevate Program risks, and ensure that system and mission safety are not compromised in an effort to optimize integration.

The ISS on-orbit configuration for a crew of two is stable and does not drive any particular Shuttle launch date. The ISS Program is maintaining assembly hardware processing activities at Kennedy Space Center to ensure that ISS hardware is ready to support assembly when the Space Shuttle returns to flight.

ISS PROGRAM IMPLEMENTATION

To support NASA's priorities of safe and effective operations, the ISS Program has adopted a development and operations schedule that is consistent with available resources. The ISS and Shuttle Programs' top-level schedules are integrated and assessed for risk through actions of the Joint (Shuttle-Station) Program Requirements Control Board. Furthermore, through implementation of several ISS Program control processes and tools, technical, cost, and schedule risks and their mitigation plans are assessed regularly.

The ISS Monthly Program Review (IMPR) ties technical, cost, and schedule status together for each performing organization and the Program as a whole, using data collected and assessed through tools and processes developed by an office created expressly to implement new Program control techniques. The IMPR comprises, in addition to in-depth reviews of integrated Shuttle-Station schedules, a detailed technical, cost, and schedule status of the ISS Program using the Web-based One NASA Management Information System (MIS) situational awareness tool. The ISS data in the One NASA MIS enable senior managers in the Space Flight Enterprise to review Program performance indicators and risk assessments on a near real-time basis (figure 6.2-1-1). Central to this dataset are the key program performance indicator metrics, sorted by red-yellow-green urgency/impact coded arrows, and backed by more detailed, manager-level performance metrics. These metrics include a Program-wide Performance Measurement System based on earned-value management concepts and technical, cost, and schedule risk status directly from the ISS Risk Management Application (IRMA).

In addition to the IMPR, the ISS Program management team receives an Early Warning System (EWS) monthly report that includes in-depth assessments of ISS business data (tied to schedule and technical status), Performance Measurement System, the One NASA MIS performance indicators, and a Quantitative Risk Assessment of those IRMA risks that are on the official ISS threats list. Special assessments are performed as needed and documented either as special sections of the EWS or as standalone reports. All EWS reports and other ISS assessment products are accessible via the One NASA MIS.

The Deputy Associate Administrator for ISS and Space Shuttle Programs and the Space Flight Leadership Council review overall Shuttle and ISS schedules.

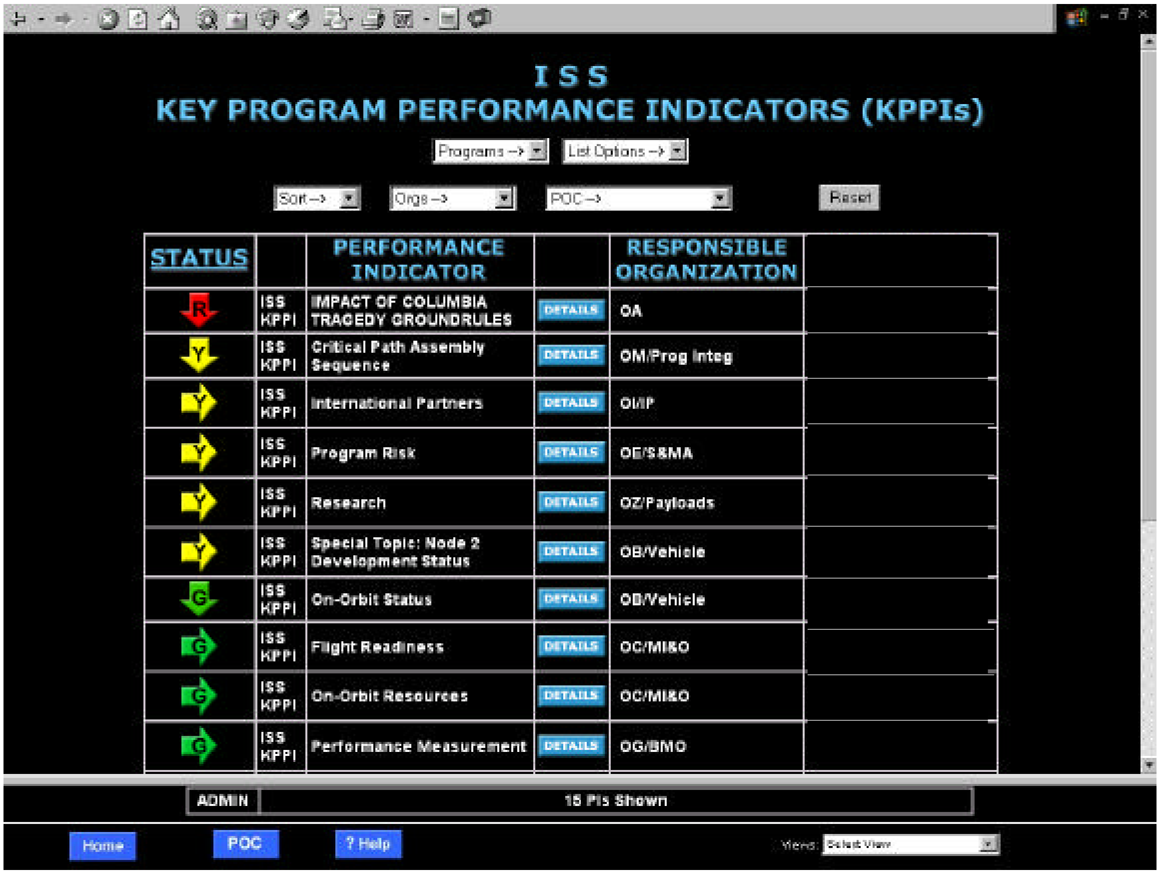


Figure 6.2-1-1. ISS key Program performance indicators.

STATUS

A series of assessments of technical, cost, and schedule issues and risk is in work to provide ISS management with the increased information necessary to support Shuttle return to flight decisions.

FORWARD WORK

Ongoing efforts to improve ISS Program control tools and processes will continue.

ISS ground rules and constraints documentation is being reviewed to identify and resolve issues that apply to scheduling and performing mission objectives (e.g., back-to-back extravehicular activities).

SCHEDULE

Due Date	Activity/Deliverable
In work	Continue assessment of technical, cost, and schedule issues to support Shuttle return to flight decisions

Columbia Accident Investigation Board

Recommendation 6.3-1

Implement an expanded training program in which the Mission Management Team faces potential crew and vehicle safety contingencies beyond launch and ascent. These contingencies should involve potential loss of Shuttle or crew, contain numerous uncertainties and unknowns, and require the Mission Management Team to assemble and interact with support organizations across NASA/Contractor lines and in various locations. [RTF]

BACKGROUND

Like the Shuttle Mission Management Team (MMT), the International Space Station (ISS) Mission Management Team (IMMT) is responsible for providing programmatic oversight and management direction associated with on-orbit operations of the ISS. The IMMT is responsible for making programmatic and technical decisions on behalf of the ISS Program when decisions must be made outside of the established mission rules and procedures, when on-orbit mission priorities must be adjusted, and when anomalous conditions present a change in risk to the vehicle, crew, and mission success. The ISS Program has initiated a review of the IMMT charter and processes, including the adequacy of relevant training plans.

ISS PROGRAM IMPLEMENTATION

With ISS operations ongoing, the IMMT is continually expected to perform with the rigor and discipline necessary to execute its responsibilities. As documented in its charter, the IMMT meets twice per week to review the status of ongoing ISS operations. During critical ISS operations, the IMMT meets more frequently. The IMMT Executive Secretary maintains a current list of contact information for all IMMT members, and this information is updated regularly.

The IMMT charter has been updated to take into account lessons learned in operating ISS for 5 years, and recommendations from the *Columbia* Accident Investigation Board. The updated charter is in the final stages of review and will then be submitted to the Space Station Program Control Board (SSPCB) for approval. Important modifications to the charter include:

1. Strengthening the process for the review and disposition of on-orbit anomalies and issues.
2. Clearly stating the responsibilities of all IMMT members, including International Partner representatives.
3. Defining procedures for calling a special IMMT, when decisions are needed before the next regularly scheduled IMMT.
4. Clarifying the role of the IMMT in certifying ISS readiness for major mission activities or events.

Training for IMMT members is documented in work instructions that govern the support that key organizations play in support of the IMMT. Many of these work instructions have been updated in support of this action. The remaining work instructions will be updated to capture training requirements tailored to each individual member.

Training exercises are scheduled for the IMMT, in support of critical first-time activities such as crew exchange on a Soyuz. These simulations include contingency cases that are specifically designed to exercise the decision-making process of the IMMT.

The IMMT is also planning simulations of ISS on-orbit failures that may result in emergency scenarios, including emergency evacuation of the crew. These simulations will include management personnel (i.e., IMMT members) from all Program organizations.

To further ensure that joint MMT/IMMT processes are integrated, the ISS Program is participating with the Space Shuttle Program in defining joint simulation cases and will participate fully in all on-orbit training planned for the Space Shuttle MMT.

STATUS

The updated IMMT charter is in the final stages of review and will be brought to the SSPCB for formal baselining before the end of November 2003.

In addition, some members of the IMMT, including the chairperson and alternate chairperson, have received cultural awareness training. One of the objectives of this training is to sensitize decision makers and meeting leaders to their responsibilities to ensure that all viewpoints are heard and properly addressed.

The ISS Program is joining with the Space Shuttle Program in planning human factors and decision-making training for its members. For example, IMMT members will be given a class on Crew Resource Management in January/February 2004.

FORWARD WORK

Ensure that all training requirements are properly documented, and that these requirements are properly implemented.

SCHEDULE

Due Date	Activity/Deliverable
Nov 2003	Complete update and approval of IMMT charter
Dec 2003	Complete documentation of IMMT training requirements

Columbia Accident Investigation Board

Recommendations R7.5-1, R7.5-2, and R9.1-1

R7.5-1 Establish an Independent Technical Engineering Authority that is responsible for technical requirements and all waivers to them, and will build a disciplined, systematic approach to identifying, analyzing, and controlling hazards throughout the life cycle of the Shuttle System. The independent technical authority does the following as a minimum:

- Develop and maintain technical standards for all Space Shuttle Program projects and elements
- Be the sole waiver-granting authority for all technical standards
- Conduct trend and risk analysis at the subsystem, system, and enterprise levels
- Own the failure mode, effects analysis and hazard reporting systems
- Conduct integrated hazard analysis
- Decide what is and is not an anomalous event
- Independently verify launch readiness
- Approve the provisions of the recertification program called for in Recommendation 9.1-1

The Technical Engineering Authority should be funded directly from NASA Headquarters, and should have no connection to or responsibility for schedule or program cost.

R7.5-2 NASA Headquarters Office of Safety and Mission Assurance should have direct line authority over the entire Space Shuttle Program safety organization and should be independently resourced.

R9.1-1 Prepare a detailed plan for defining, establishing, transitioning, and implementing an independent Technical Engineering Authority, independent safety program, and a reorganized Space Shuttle Integration Office as described in R7.5-1, R7.5-2, and R7.5-3. In addition, NASA should submit annual reports to Congress, as part of the budget review process, on its implementation activities. [RTF]

BACKGROUND

Prior to Space Shuttle return to flight (RTF), as called for in recommendation 9.1-1, NASA will develop a comprehensive plan with concrete milestones leading us to a revised organizational structure and improved management practices, and implementing *Columbia* Accident Investigation Board (CAIB) recommendations 7.5-1 through 7.5-3. Over the next several months, NASA will report to Congress progress on development of options and milestones. The International Space Station (ISS) Program is a participant in this process.

NASA is committed to change the Agency's organizational structure to facilitate a culture that ensures that we can manage and operate our human space flight programs safely for years to come. Our organization's culture did not successfully embrace a robust set of practices that promoted safety and mission assurance as priorities. As stated within the CAIB report, there was evidence that safety was compromised by leadership and communication problems, technical optimism, emphasis on schedule over safety, and funding problems.

Changing NASA's culture is a significant and critical undertaking. We must put in place structures and practices that continually emphasize the critical role of safety and mission assurance while we adhere to sound engineering practices, and move toward a long-term cultural shift that values these practices. We must have the ability to search for vulnerabilities and anticipate risk changes. The character of our culture will be measured by the strength of NASA's leadership commitment to continuously improve safety and engineering rigor, and to share and implement lessons learned. This will allow us to improve safety by asking probing questions and elevating and resolving issues. Our culture must be institutionalized in an organizational structure that assures robust and sustainable checks and balances. The resulting organizational and cultural changes will balance the roles and responsibilities of Program management, technical engineering, and safety and mission assurance, while clarifying lines of authority for requirements. We must institutionalize an engineering quality and safety culture that will become embedded in our human space flight program even as personnel or organizations change. This cultural transformation will require changes to the way we manage all of our programs, institutions, budgets, and human capital.

Although implementation will be as rapid as possible, we must take the time necessary to understand and address the risk posed by introducing changes into complex problems. As the CAIB report states, "Changes in organizational structure should be made only with careful consideration of their effect on the system and their possible unintended consequences."

NASA is committed to assessing our options, understanding the risks, selecting the appropriate option, and implementing the needed change. We will dedicate the resources to accomplish these tasks.

ISS PROGRAM IMPLEMENTATION

Recognizing the need to make significant managerial and organizational changes to address the deficiencies that led to the *Columbia* accident, NASA has already begun to implement a number of improvements. Guided by the CAIB report, we will analyze and create an implementation strategy to ensure that each of the CAIB's recommendations is met. The Office of Safety and Mission Assurance has been assigned as the focal point for this recommendation.

STATUS

As a preliminary first step, based on the early recognition of the need for enhanced engineering and safety organizations, NASA recently established the NASA Engineering and Safety Center (NESC) at the Langley Research Center to provide independent engineering and safety assessment. The NESC will be operational by November 2003, and will further augment the Office of Safety and Mission Assurance's independent engineering and safety assessment capability. The NESC is the catalyst that will invigorate engineering excellence and strengthen the safety culture within NASA. The Headquarters Office of Safety and Mission Assurance will provide the NESC's budget and policy to assure independence. The NESC's charter includes, but is not limited to, the following:

- A centralized location for the management of independent in-depth technical assessments for safety and mission assurance, engineering, and the Shuttle and ISS Programs. This will be supported by expert personnel and state-of-the-art tools and methods.
- Independent testing to determine the effectiveness of problem resolutions or to validate the expected outcomes of models or simulations.
- Independent safety and engineering trend analyses.

In addition, NASA is improving and strengthening current Shuttle and ISS Program management, engineering, and safety processes. However, the criticality of fully understanding all aspects of the CAIB recommendations requires a complete and thoughtful evaluation and response. These recommendations will result in major organizational changes. NASA's priority is to fly safely while successfully executing our mission for the nation.

FORWARD WORK

NASA is committed to making the organizational and cultural changes necessary to respond to CAIB recommendations 7.5-1 and 7.5-2. The process of implementing and institutionalizing these changes will include investigating funding paths; determining requirement ownership; identifying Certification of Flight Readiness responsibility; and specifying responsibility within the human space flight enterprise for cost, schedule, and technical issues.

NASA will form an interdisciplinary team, including representation from the ISS Program, to assess these issues to develop a detailed plan prior to RTF as required in recommendation 9.1-1.

Columbia Accident Investigation Board

Recommendation 7.5-3

Reorganize the Space Shuttle Integration Office to make it capable of integrating all elements of the Space Shuttle Program, including the Orbiter.

BACKGROUND

The complexities of the International Space Station (ISS) Program, including the international partnering structure, the on-orbit assembly and integration, and the requirement for continuous operation and utilization across all phases of assembly, have necessitated a strong focus on integration since Program inception. As the ISS integrator, NASA has led the multilateral definition of integration processes that govern ISS design, development, operation, and utilization. The Boeing Company, as the ISS Prime contractor, is responsible for technical integration of the end-to-end ISS. In addition, NASA, with Boeing, integrates the ISS transportation requirements across an international mix of space transportation systems (such as the Space Shuttle, Soyuz, Automated Transfer Vehicle, and H-II Transfer Vehicle). NASA recognizes that this unique mix of organizational cultures and dependencies makes the Program integration function crucial to assuring ISS Program objectives are met, and all issues and anomalies are resolved in a timely manner.

NASA assures that all program elements comply with the Program requirements and strategic objectives. With no precedent or blueprint for an international collaboration of this scale and complexity, NASA has evolved a centralized framework that integrates top-level decision-making across the partnership. In parallel, a decentralized framework at the worker level enhances communication and collaboration. Issue identification and resolution are integrated across teams and working groups that often include members separated by geography, time zones, language, and culture. This approach is key to early identification of potentially significant issues and provides multiple reporting outlets to senior managers—in real time through the ISS Mission Management Team; or through the governing boards, Safety community, or ISS risk management process. NASA recognizes that effective communication is a critical factor in successfully executing the Program integration function.

ISS PROGRAM IMPLEMENTATION

NASA has consolidated top-level technical integration functions in the ISS Program Integration Office. The Program Integration Control Board has decision authority to review and approve changes and actions at the ISS system level, and includes voting members from all major ISS organizations, Safety, the Engineering Directorate, Mission Operations Directorate, and Crew Office. The ISS Program Integration Office chairs the Multilateral Program Integration Control Board (MPICB) to address issues that affect more than one ISS Partner. In addition, joint Station-Shuttle technical issues are reviewed at joint Station-Shuttle boards. The ISS Program Integration Office participates in these joint Boards.

The Program Integration Office performs the classical systems engineering and integration (SE&I) function across multiple disciplines to assure overall integrated ISS functionality. The Program Integration Office performs SE&I assessments to optimize integrated vehicle performance, vehicle resources, external configuration, system architecture, and mission design. In addition, the office manages the top-level ISS specifications, interface control documents, and drawings.

The Program Integration Office also is responsible for technical integration of assembly elements provided by the Russian Space Agency, the European Space Agency, the Japanese Aerospace Exploration Agency, and the Canadian Space Agency. The MPICB reviews and approves technical integration decisions that affect two or more Partners.

One example of an ISS integration activity is the Stage Integration Review. The Stage Integration Review team conducts ISS Program-wide reviews of ISS flights approximately 20 months prior to launch to ensure the initial operational procedures match Program needs and vehicle performance capabilities. NASA chairs a line-by-line multilateral or bilateral review, as required, of the designated flight's Assembly and Operations Support Plan. This exhaustive review has proven effective in both identifying and amplifying the *"weak signals"* that otherwise might have gone unnoticed.

STATUS

Strategic processes and products ultimately feed the tactical integration processes and products that facilitate manifest preparation, flight and increment management, and ISS operation. Strategic analyses also are integral to NASA's ability to manage crew timelines. NASA is in the process of reexamining and clarifying interorganizational roles and responsibilities to ensure seamless transition from strategic to tactical integration.

In addition, a key Program Integration objective is to achieve a smooth transition in accordance with the new contract consolidation strategy driven by the natural evolution from developmental to operational activities. Certain integration tasks previously performed by Boeing as the Prime contractor are transferring to new contractors. The challenge is to ensure there are no contractual barriers to impede integration across the contracts.

FORWARD WORK

Continuously strengthen ISS Program integration functions and organizational responsibility as conditions warrant and contractual arrangements change. Continuously strengthen the Program Integration Office role in control and monitoring of all hardware and system performance interfaces.

SCHEDULE

Due Date	Activity/Deliverable
Nov 2003 (under review)	Complete transition from strategic to tactical integration
Dec 2003	Complete contract consolidations

Columbia Accident Investigation Board

Recommendation 9.2-1

Prior to operating the Shuttle beyond 2010, develop and conduct a vehicle recertification at the material, component, subsystem, and system levels. Recertification requirements should be included in the Service Life Extension Program.

The underlying intent of this recommendation is addressed in Part 2, ISS Continuous Improvement Action ISS-7.

Columbia Accident Investigation Board

Recommendation 10.3-1

Develop an interim program of closeout photographs for all critical sub-systems that differ from engineering drawings. Digitize the closeout photograph system so that images are immediately available for on-orbit troubleshooting. [RTF]

BACKGROUND

The nature of International Space Station (ISS) operations dictates that careful attention is placed on closeout imagery requirements in support of complex assembly operations, as well as on remote inspection and maintenance of ISS systems. Images are also used to support systems performance analyses and failure investigation. The ISS Program established the requirements to obtain images from hardware as it is built up into assemblies for launch. Lessons learned while operating ISS for almost 5 years have highlighted the importance of closeout imagery and led to strengthening of closeout imagery requirements and database management.

ISS PROGRAM IMPLEMENTATION

To ensure safe and effective ISS operations, the ISS Program requires that imagery records be maintained beginning with hardware manufacturing through on-orbit assembly, operations, and maintenance. The ISS Program uses preflight and closeout imagery to document the "as flown" configuration of the modules/elements and hardware that comprise the ISS.

Images are used to support remote maintenance and inspection of ISS systems. Images are exchanged between the crew and the ground in support of ISS systems maintenance and operation. The adequacy of on-orbit ISS imagery in support of ISS systems maintenance is discussed in response to R6.4-1.

Imagery is also used in real time to support assembly operations. All ISS assembly tasks are designed to ensure that adequate imagery is provided to the crew and the ground.

In response to the *Columbia* Accident Investigation Board recommendations, this entire process was reviewed and found to be adequate.

Imagery Management

The Imagery Working Group (IWG) is responsible for managing and integrating all imagery activities for the ISS. These activities include coordinating and developing imagery requirements for all customers; acquiring, distributing, and archiving ISS imagery; defining and procuring ISS imagery-related flight and training equipment; and resolving ISS imagery issues. The IWG consists of representatives across NASA and the ISS International Partners.

The ISS Program has a dedicated database, the Digital Imagery Management System (DIMS), containing preflight and closeout images, as well as on-orbit images. Imagery is retrievable from the DIMS upon demand. Equally, the Video Asset Management System database contains all preflight, downlinked, and returned ISS video.

A complete imagery record of the integrated ISS configuration and crew assembly activity is maintained. These requirements are documented in SSP 50261-01, Generic Ground Rules, Requirements and Constraints, Part 1: Strategic and Tactical Planning. This record is required to support planning for assembly and maintenance, training of crew members, and failure analysis. It includes imagery to support the following important ISS functions:

1. Ensure the safety of the on-orbit crew and vehicle.
2. Support the successful assembly, maintenance, operations, and utilization of ISS, including preflight and closeout imagery.
3. Document the configuration and monitor the overall condition of ISS.
4. Evaluate the performance of the vehicle and space operations.
5. Support problem solving and troubleshooting of assembly, maintenance, operations, anomaly, and contingency functions.

6. Document crew activity (internal and external to ISS) and Earth observation.
7. Provide information about ISS activities to educational outlets, the public, and national and international media sources.

The following provides descriptions of each functional area. The procedures and processes, technical as well as managerial, associated with each of these functional areas were assessed and considered adequate.

Preflight Closeout Imagery

The ISS Program uses preflight closeout imagery to document the "as flown" configuration of the modules/elements and hardware that comprise the ISS. This imagery is primarily used to support planned and unplanned on-orbit maintenance, crew training, procedure development, and sustaining engineering. Hardware providers and mission operation organizations create preflight imagery requirements. Preflight imagery for ISS hardware is acquired for the U.S. segment, as well as for International Partner-provided hardware. Imagery is submitted with sufficient cataloging data to make it retrievable in the DIMS. This preflight imagery is used for analysis to determine the on-orbit condition of the hardware.

Primary and secondary structures, wire harnesses, fluid lines, connectors, rack buildup, and interfaces to the module document the layered construction of the hardware in context. Orbital replacement units (ORUs) are spares for planned on-orbit maintenance; they are imaged before, during, and after integration, with emphasis on crew interfaces. The exterior of the module is mapped by location code, specifically the ORUs, translation paths, and workstations.

The Preflight Imagery Plan (PFIP) contains ISS imagery requirements to document configuration of the hardware. The hardware provider submits the PFIP to the ISS Program. System experts and imagery users review and modify the PFIP requirements as necessary. Individual PFIP requirements are traceable to the images in DIMS that satisfy those requirements. For each ISS flight, these images are available on line to support flight operations. Currently, the DIMS contains more than 75,000 closeout images that satisfy PFIP requirements through flight 7Soyuz. The International Partners supply an Imagery Plan at Critical Design Review that responds to ISS Program requirements to ensure adequate photographs and cataloguing of international hardware.

Specifically, at the Kennedy Space Center Space Station Processing Facility, ISS closeout imagery is acquired based on procedures that are documented in Boeing Standard Practice SP-QUAL-002, ISS Configured for Test, and in Boeing SPP-016, Standard Practice and Procedures,. The acquired closeout imagery is placed in the official ISS DIMS imagery database.

On-Orbit Operations

ISS Program participants may require acquisition of specific images to support on-orbit operations, such as routine maintenance or capturing a series of images for outreach purposes. Detailed ISS on-orbit imagery requirements are defined in the Increment Definition and Requirements Document Annex 3, which includes the integrated on-orbit imagery requirements for each flight and increment stage. These requirements are used to develop the imagery Operations Data File (ISS Photo/TV procedures), and the operations timelines, crew training plans, and imagery distribution requirements.

Any planned on-orbit hardware reconfiguration is documented in Annex 3 and requires closeout imagery. Unplanned on-orbit reconfiguration of the hardware is documented and implemented with written procedures, which require closeout imagery of the completed configuration changes. This imagery is then used to update engineering drawings.

Ground Operations

The Mission Operations Directorate Photo/TV group provides integrated imagery task instructions to ISS crews. This includes video system training necessary to acquire high-quality imagery, in-flight Photo/TV procedures and flight execution, as well as electronic still photography and video downlink training. Real-time mission support is provided through the flight control team under the leadership of the flight directors. After every flight, any techniques and processes determined needed to improve tasks are implemented.

The Information Resources Directorate at JSC is responsible for the reception, processing, retention, and distribution of video and still imagery acquired on board the ISS. Downlinked imagery, transmitted from either the Space Shuttle or the ISS, is received at the Mission Control Center via the Space to Ground Network. It is then transmitted to the JSC Video Control Center or the Digital Imaging Laboratory. There the imagery is recorded, cataloged, archived, and distributed, per ISS

Program requirements. Imagery is available through request to the Public Affairs Office.

The JSC Image Science and Analysis Group (IS&AG) provides analyses and assessments of ISS from the photographic and video imagery acquired from ISS- and Shuttle-based cameras. Image analysis personnel and the facility, the Video Digital Analysis System, provide a full range of imagery processing, enhancement, and analysis services in support of ISS troubleshooting and problem solving, assembly, maintenance, vehicle performance, operations, anomalies, and contingencies. The ISS Mission Evaluation Room directs, in real time, the IS&AG support for troubleshooting and anomaly analysis. A wide range of other analyses, such as appendage motion studies, docking performance, and vehicle configuration, is performed at the direction of Engineering, Mission Operations, or the ISS Program. IS&AG sponsors the ISS External Survey, a periodic inspection of the ISS exterior to detect and assess damage or changes over time. The images from these surveys are analyzed; and, if inadequate, higher-fidelity images are obtained via other on-board cameras or improved viewing angles.

FORWARD WORK

The ISS preflight imagery process has been in place for the last 5 years and has evolved into a mature process.

The imagery format has evolved from 35mm film to digital high-resolution format. Digital technology is constantly being researched to apply to preflight and other ISS imagery. For example, the ISS Program is actively prototyping High Definition Television downlink for future use on ISS.

Preflight imagery for International Partner modules being integrated and processed at Kennedy Space Center will be acquired per existing requirements. Additionally, ongoing reviews of the preflight imagery plans are performed to ensure that all future modules/hardware are fully compliant with ISS Program imagery requirements.

The ISS Program is studying improvements in the process used to capture differences between on-orbit configuration and the engineering drawings, as required (reference R10.3-2) and whether additional on-orbit imagery is required.

SCHEDULE

Due Date	Activity/Deliverable
Complete	Process review for adequacy

Columbia Accident Investigation Board

Recommendation 10.3-2

Provide adequate resources for a long-term program to upgrade the Shuttle engineering drawing system including

- Reviewing drawings for accuracy
- Converting all drawings to a computer-aided drafting system
- Incorporating engineering changes

BACKGROUND

The International Space Station (ISS) has been designed, developed, and manufactured, and will be operated by many organizations from around the globe. The nature of the Station has dictated that careful attention is placed on development, control, and rapid access to engineering data (i.e., drawings). With this in mind, NASA's strategy from ISS initiation has been to develop and implement an electronic drawing system.

Detailed drawings of International Partner hardware are maintained by the International Partners. Agreements are in place to share the necessary information in support of on-orbit ISS anomaly resolution.

ISS PROGRAM IMPLEMENTATION

ISS drawings reside in the Vehicle Master Database (VMDB). The VMDB has been in operation since 1995. It is a centralized repository that provides ISS with the authoritative source of engineering and operations drawings and data. Also, it provides access to view and print engineering drawings, associated lists, parts lists, and engineering orders (EOs).

The VMDB drawings interface is presently the most widely used feature of the VMDB. VMDB drawings are easily accessible and available to all Program participants. Examples include:

- The Mission Evaluation Room and the Engineering Support Room use VMDB for sustaining engineering and real-time operations.
- The Vehicle Integrated Performance and Resources team uses VMDB to perform resource analysis and allocation.
- The Mission Operations Directorate uses VMDB for Flight Operations and ISS Operations.
- The Manifest Working Group uses VMDB as the data repository and tool to deliver the Program Approved Manifest and the Planned Manifest Change.

STATUS

To date, there are approximately 79,000 drawing entries, including 48,500 unique drawings with their revisions. Released engineering data, including drawings and advanced EOs, continue to be loaded daily into the VMDB. Government-furnished data and International Partner (to a higher level) and subcontractor drawings continue to be delivered and loaded. ISS On-Orbit Stage Drawings are also being delivered and loaded on a regular basis.

FORWARD WORK

Portions of the VMDB, which are in portable document format (.pdf), are currently scheduled (first quarter of fiscal year 2004 (FY2004)) to be integrated into a new product data management system called the ISS Electronic Document Management System. With this tool, integration of documents from different sources will be accomplished in the near future.

SCHEDULE

Due Date	Activity/Deliverable
First quarter FY2004	VMDB integration to Electronic Document Management System
Continuous	Complete loading of additional drawings

Part 2
International Space Station Continuous Improvement Actions

This section details specific actions that the International Space Station (ISS) Program has undertaken as a result of internal recommendations over and above those made by the Columbia *Accident Investigation Board.*

Within hours of the Columbia *tragedy, the ISS Program formed teams to review the requirements, potential hazards, and risks associated with maintaining a continued crew presence on ISS with no Space Shuttle support. This comprehensive effort reviewed areas such as on-board availability of consumables and spare parts, hardware lifetime and certification issues, and capabilities for supporting ISS and its crew with only Russian Progress and Soyuz vehicles. All ISS Partners agreed to the strategies necessary to continue with crewed operation of ISS.*

(Continued on back)

Over time, the ISS Program Manager initiated several actions to assess our overall risk posture in the current situation. An effort was made to reassess previous decisions to accept risk in light of observed performance of the ISS on orbit and the changes in plans from when risk was accepted. The reviews were done with the CAIB report in mind and its mandate to avoid the trap of being lured into thinking that low-probability events will not happen simply because they have not happened in the first few years of ISS operations.

Program teams were asked to review the entire list of Program-approved items (waivers, deviations, exceptions, etc.) that identified significant accepted risk. The teams applied two major tests: 1) Had changes in the Program or the performance of the Space Station on orbit significantly changed the context of approval of individual items; and 2) Did the items in aggregate introduce significant additional risk that was overlooked as the items were approved individually. The experts most knowledgeable about the item were involved in the evaluation. This section describes those actions and the current status of each. Subsequent versions of this plan will contain updated status of continuous improvement actions.

ISS Continuous Improvement Actions

ISS Continuous Improvement Action 1

The ISS Program will review all Program waivers, deviations, and exceptions for validity and acceptability.

BACKGROUND

The International Space Station (ISS) Program process for granting waivers, deviations, or exceptions is based upon a system risk assessment of the specific inability to meet the requirement. If the risk assessment shows adequate risk mitigation actions are in place to prevent any serious consequence, the risk mitigation action is granted. These exemptions are formally tracked and reviewed any time a flight activity could be adversely affected. Because waivers, deviations, and exceptions to ISS Program requirements contain the potential for unintended risk, the ISS Program has directed all elements to review these exemptions to Program requirements to determine whether the exemption is still valid in light of nearly 5 years of on-orbit ISS operational experience.

In addition, the ISS Program will evaluate the exemptions to assess whether the totality of exemptions carries additional risk. Particular attention is being placed on the exemptions that carry safety risks of a catastrophic nature with a short time to effect.

ISS PROGRAM IMPLEMENTATION

There are currently over 700 waivers, deviations, and exceptions to ISS Program requirements. The task of reviewing these exemptions is being executed in two phases.

Phase 1: Each waiver, deviation, and exception will be reviewed by ISS Program personnel under the auspices of the appropriate Program control board based on the following ground rules:

1. Determine if risk posture has changed in light of the *Columbia* tragedy or since observed operation of ISS.
2. Determine if modifications should be considered to the vehicle or the requirements in light of a changed risk posture.
3. If the same requirement impacts several deviations/waivers/exceptions, review and determine whether the requirement should be changed.
4. Review the waivers, deviations, and exceptions for cumulative risk due to an accumulation of accepted risk over time.

Phase 2: The ISS has created a Tiger Team of ISS system experts to look at each of the items not judged to have a previous disposition as valid or overcome by events. This team has been tasked to develop an in-depth risk assessment for potential impacts to ISS. Further, this team will review the cumulative impacts of each of these approved exemptions to overall ISS risk. The team is tasked to review the exemptions from an integrated system approach and to look for interdependencies between individual exemptions. The risk assessments and mitigation plans will be tracked in the ISS Risk Management system.

STATUS

Phase 1 review and categorization of the waivers, deviations, and exceptions is nearing completion. Of the 722 exemptions, 593 have been reviewed and categorized as follows.

1. Previous disposition valid – 481
2. Risk unacceptable; definitely need to re-review risk posture accepted by NASA – 5
3. Undetermined; need more time, analysis, review as an integrated system or an area of concern – 40
4. Overcome by events; no longer applicable – 67

In addition to the above exemptions, the ISS Program reviewed 59 Criticality 1 Software Program Notes (SPNs). SPNs are notes documenting problems or operational issues with Program software. The SPNs have been reviewed and, where appropriate, assigned for closure in future releases of ISS software.

The ISS Program also reviewed 19 waivers to the Generic Ground Rules and Constraints document. While each of these waivers is considered to be valid or overcome by events, activities have been initiated to determine whether changes can be made to operational plans to eliminate the need for these waivers.

There are additional waivers, deviations, and exceptions to Kennedy Space Center (KSC) processing requirements. A senior technical board was established to review these exemptions, and the activities of this board will be completed by December 2003.

FORWARD WORK

Finish the review and categorization of all waivers, deviations, and exceptions. Complete the in-depth Tiger Team review and analysis to identify any technical items requiring further work.

SCHEDULE

Due Date	Activity/Deliverable
Oct 2003	Complete final categorization of remaining exemptions
Nov 2003	Complete Phase 2
Dec 2003	Complete review of KSC hardware processing exemptions

ISS Continuous Improvement Actions

ISS Continuous Improvement Action 2

The International Space Station Program will review all hazard report nonconformances, regardless of classification, to review rationale for acceptance of these "accepted risks."

BACKGROUND

International Space Station (ISS) safety analysis is accomplished by performing a top-down assessment of hazards and identifying the events that could lead to those hazards. The results of these analyses are captured in hazard reports. The ISS Program has established safety requirements designed to provide the necessary control of hazards. The highest safety risk to the ISS and its crew is represented by a failure to meet ISS safety requirements. For environmental- or operational-induced risks, hazard reports are prepared. When a safety requirement is not met and the ISS Safety Review Panel feels that the risk is adequately controlled, a nonconformance report (NCR) to the hazard report is generated to justify and accept the risk. As a result of the *Columbia* accident, the ISS Safety Review Panel (SRP) conducted a review of each NCR to determine whether the ISS Program should revisit the associated accepted safety risks. This activity reviewed the assumptions and ground rules used when the NCR was accepted to assess whether they were still valid. Many steps were taken to provide a level of confidence on how the original NCRs compare to the current ISS conditions and operations. This assessment has been completed, and this summary briefly describes those steps and provides the results of that assessment.

ISS PROGRAM IMPLEMENTATION

The ISS SRP identified several potential sources of ISS changes that could have impacted the NCR assumptions. These areas included how the current ISS environment compares to the assumed environment when the NCR was approved; how the current ISS operations compare to the operations assumed when the NCR was approved; additional data that would question the validity of the rationale on the NCR; how ground test or on-orbit anomalies may have weakened the retention rationale features; and any changes in detectability of failures that could contribute to the hazard manifesting itself since the NCR was originally approved. These criteria were used to assess each existing ISS NCR.

Ground rules were established to limit the review of NCRs to those carrying the greatest amount of Program risk and affected by anomalous performance. For example, NCRs addressing the control of touch temperatures were not reassessed because the associated risks are well managed with operational controls. On-orbit anomalies with safety implications were reviewed to see if they had any impact on NCRs. The decision to limit the review of anomalies to on-orbit anomalies was based on the fact that most ground test failures result in restoration of function or design back to compliance with the specifications and drawings.

NCRs impacted by the defined criteria were categorized as follows:

1. No Significant Impact – No Changes/Action required.
2. Minor Impact – Recommend NCR update and subsequent NCR re-approval/signature.
3. Major Impact with Acceptable Risk Mitigation – Recommend rewrite of NCR with subsequent full panel review and re-approval.
4. Major Impact with Potentially Unacceptable Risk – Reopen NCR and go to full SRP for proper action assignments to resolve.

It was determined that one NCR had a "Major Impact with Potentially Unacceptable Risk." The NCR addressed a Space Shuttle failure mode that could affect ISS. Specifically, the Space Shuttle Reaction Jet Driver does not have adequate failure tolerance to control against an inadvertent Space Shuttle Orbiter primary jet firing when attached to ISS. The ISS SRP determined that the hazard exposure was greater than was considered at the time of acceptance of the NCR and asked that the Space Shuttle and ISS Programs revisit this issue. This work has been initiated.

Not specifically covered by an NCR, yet considered very important by the ISS SRP, is the ISS external Thermal Control System robustness to failure situations. In response to this concern, the ISS Program initiated development of electrical power jumpers that remove the risks associated with certain external thermal system failures.

Four NCRs had “Major Impact with Acceptable Risk Mitigation.” These included three Russian Segment micrometeoroid and orbital debris NCRs, for which Russian delays in implementing enhanced protection have occurred. Together with our Russian Partners, the ISS Program has taken steps to mitigate these risks. One NCR addressed a system issue that has since been resolved.

STATUS

In response to the changed risk posture identified by this review, the ISS Program has taken concrete action to mitigate risks.

FORWARD WORK

All NCRs will be updated to accurately reflect the risk being accepted by the ISS Program. The SRP will review all revised NCRs for concurrence.

SCHEDULE

Due Date	Activity/Deliverable
Sep 2003	Complete NCR Review
Under Review	Agree on risk mitigation plan for Space Shuttle Reaction Jet Driver hazard

ISS Continuous Improvement Actions

ISS Continuous Improvement Action 3

The ISS Program will review its Certification of Flight Readiness (CoFR) process and identify areas for improvement.

BACKGROUND

The International Space Station (ISS) Certification of Flight Readiness (CoFR) process enables certification of the safety and operational readiness of the ISS Program hardware, software, facilities, and personnel that support prelaunch activity, launch, return, on-orbit assembly, operations, and use of the ISS. Additionally, the CoFR process enables the assessment and certification of the successful completion of activities that are required to ensure mission success. Certifying organizations (ISS Program contractors, International Partners, ISS Program organization managers, and other NASA institutional managers) use the CoFR process to provide endorsements to the ISS Program before committing to flight and continued ISS operations.

ISS PROGRAM IMPLEMENTATION

The ISS Program formed a team to assess the adequacy of its CoFR process and to make recommendations for improving the way we review the risks accepted when committing to flight and continued operation of the ISS. This assessment included a process review, a documentation review, and an audit of the key processes used by certifying organizations in making their endorsement decisions. In addition, the ISS Program requested that a representative of the Independent Assessment Office (IAO) work with the ISS Program review team and provide an independent assessment of the team's work and of the CoFR process itself.

STATUS

ISS Program management received and reviewed initial recommendations from the CoFR team in early September. This early release of important findings allowed the ISS Program to implement several improvements in time for the Stage Operations Readiness Review and Flight Readiness Review conducted in preparation for the launch of the Expedition 8 crew on 7Soyuz. Specific changes included additional guidance on the content of CoFR review presentations, with an increased focus on the risks associated with operations and hardware flown for the first time. This process was successfully executed during the 7Soyuz Stage Operations Readiness Review and Flight Readiness Review as all Program elements fully discussed concerns surrounding the ISS environmental monitoring capability. When concerns with the adequacy of ISS environmental monitoring were brought to the Stage Operations Readiness Review, these concerns were openly discussed and actions were put in place to ensure that all possible steps to mitigate risk were taken. The concerns and mitigating actions were fully discussed at the Flight Readiness Review, where NASA management decided to proceed with the launch of the Expedition 8 crew.

The NASA IAO provided an initial report on the CoFR process to the ISS Program, and this report was consistent with the observations of the ISS Program review team.

FORWARD WORK

The ISS Program will continue to review the recommendations of the IAO and its own COFR review team. It will also assess the conclusions and changes of the Space Shuttle Program for potential ISS applicability.

The ISS Program is committed to implementing the recommendations of the ISS Program review team and the IAO. The ISS Program has assigned the ISS Mission Integration and Operations Office the task of responding to each of the recommendations within 60 days.

SCHEDULE

Due Date	Activity/Deliverable
Sep 2003	Initial recommendations
Under Review	Complete implementation of CoFR process review team recommendations

ISS Continuous Improvement Actions

ISS Continuous Improvement Action 4

The ISS Program has initiated a review of its critical items lists (CIL) and the failure modes and effects analyses (FMEAs) associated with the CIL to revalidate acceptance rationale based on experience gained in operating a crewed ISS for almost 3 years.

BACKGROUND

A purpose of the failure modes and effects analysis/critical items list (FMEA/CIL) is to identify potential hardware failure modes and their credible causes, and to assess their worst-case effect on International Space Station (ISS) operations and crew/ISS survival. A subset of the hardware analyzed in FMEA is categorized as a critical item based on the risks from failure and the corresponding criticality classification assigned. For these critical items, an acceptance rationale is documented that minimizes the failure probability and/or precludes the failure effect.

As part of the ISS design process, the ISS Program performed the following steps:

1. Developed an FMEA on all ISS hardware to identify critical items.
2. Identified essential manufacturing inspection and test processes for critical items to eliminate or further reduce the risk. Consideration is given to enhancing the hardware design by focusing on design specification, qualification, and acceptance requirements.
3. Formulated operational and maintenance procedures for critical items to eliminate or minimize the likelihood of occurrence and the effect associated with each failure mode.
4. Formally documented the acceptance rationale identified for each failure mode in the CIL retention rationale and provided assurance that the critical item controls are effectively implemented.

ISS PROGRAM IMPLEMENTATION

The ISS Program is revalidating all ISS critical items along with their FMEA. All ISS critical items have been reviewed by the ISS Reliability and Maintainability (R&M) Panel, with the support of the ISS Safety and Mission Assurance (S&MA) subsystem engineers, to capture any on-orbit or ground processing experience that has impacted CIL retention rationale. The results of this initial review have shown that the ISS CIL retention rationale is still valid. Several enhancements have been identified to reinforce the role of the ISS CIL in assessing the most significant Program risk contributors. For example, it has been recommended that CIL retention rationale be updated as needed with on-orbit/ground failure history to ensure current and accurate documentation, and progressive control of Program risks.

The ISS Program subsystem teams will participate in this effort by reviewing these findings and identifying the FMEA/CILs that warrant revalidation based on their respective criticality and experience gained to date. Revalidation efforts include the following:

1. Validating the retention rationale associated with each critical item to ensure that the level of risk initially accepted by the ISS Program has not changed.
2. Establishing new or modifying existing retention rationale, as required.
3. Developing or revising FMEA/CIL worksheets, as required.
4. Reviewing criticality assignments for accuracy and consistency with current use and environment.
5. Submitting revised critical items to the S&MA Panel and Space Station Program Control Board (SSPCB) for approval, if the level of risk is affected.

An assessment of the most significant contributors to Program risk will be performed to ensure that these risks are continually reviewed and managed by ISS Program management.

The ISS R&M Panel will serve as the forum in which to review the subsystem team assessments of the validity and applicability of the CIL retention rationale. The S&MA Panel will review any updates to baselined CILs.

STATUS

The ISS Program is reviewing and revalidating FMEA/CILs according to SSPCB approved schedules. Results, so far, show that the ISS critical item retention rationale is still valid.

FORWARD WORK

Revised critical items will be brought to the S&MA Panel and the SSPCB for approval, as required. Should any of the revised critical items be disapproved for Program acceptance, the ISS Program will assess hardware or process changes. The ISS Program will ensure that a process is in place to review and update any ISS FMEA/ CIL as the need arises through the life of the ISS Program.

SCHEDULE

Due Date	Activity/Deliverable
Sep 2003	Status Report to Program Manager
Under Review	Complete assessment

ISS Continuous Improvement Actions

ISS Continuous Improvement Action 5

Review ISS anomaly resolution processes to ensure that proper requirements are in place and anomaly resolution processes are operating effectively.

BACKGROUND

The proper identification, investigation, resolution, and reporting of International Space Station (ISS) hardware and software anomalies, whether they occur on the ground or on orbit, is essential in assuring successful activation and operation of ISS systems, overall mission success, crew safety, and effective operations and sustaining engineering.

On-orbit anomalies are identified through real-time operation and monitoring of ISS systems telemetry by the ground, from input by the crew, and through the routine evaluation of historic on-orbit performance data. The ISS Program also reviews ground-based anomalies to determine if there could be any impact to on-orbit systems that are operating nominally.

After an on-orbit anomaly has occurred, there is a well-defined process for assessing and documenting the anomaly and its potential impacts to on-orbit ISS operations. This process is understood by all the subsystem and discipline teams that support ISS on-orbit operations. The process is also used when a ground-based anomaly with potential impacts to ISS on-orbit operations has occurred. The ISS Mission Evaluation Room (MER) engineers are responsible for documenting, tracking, and resolving on-orbit anomalies. They are also responsible for fully understanding and defining on-orbit corrective actions for ground anomalies that could have on-orbit implications. This process is fully documented in the ISS Program controlled document, On-Orbit Anomaly Resolution Process Work Instruction, MGT-OA-019.

Upon occurrence of any anomaly affecting on-orbit operations, the ISS MER Manager will define the anomaly as an “item for investigation” and document what is known about the anomaly in the formal database used to track these anomalies. The ISS MER Manager will lead the ISS MER in assessing the anomaly to determine if immediate or short-term troubleshooting and/or corrective actions are required. If so, the ISS MER Manager will convene and lead a failure investigation team to address troubleshooting or corrective actions. The failure investigation team is responsible for managing all aspects of the anomaly resolution process, as it affects the on-orbit vehicle. This responsibility includes fully understanding the event and its impacts to the ISS vehicle and crew, defining further data gathering or troubleshooting requirements, recommending corrective actions, and performing final closeout and documentation of its proceedings. In some cases, an on-orbit anomaly leads to a nonconformance that may require modification of the hardware. The MER Manager uses the ISS Program problem resolution and corrective action database as the mechanism for formally logging these anomalies and the necessary associated data. From this point, the ISS Program vehicle design organization manages hardware changes.

In January 2003, the ISS Program formed a team to evaluate the current ISS anomaly resolution process, identify deficiencies, recommend and implement approved corrective actions to resolve those deficiencies, and continue to monitor the process during and following implementation of those improvements.

ISS PROGRAM IMPLEMENTATION

Review of the ISS anomaly resolution process included a review of the current ISS anomaly investigation and resolution requirements to determine their adequacy to support final assembly and long-term sustaining of ISS. The ISS Program also evaluated the ISS and Johnson Space Center tools and databases currently available to support the documentation, tracking, and disposition of ISS anomalies. The ISS Program also evaluated the current ISS anomaly investigation and resolution processes to determine how effectively the requirements are being implemented.

The review resulted in several recommended actions to improve the anomaly resolution process and to ensure consistency in anomaly resolution and anomaly documentation as well as to provide ISS management useful methods by which to assess and track anomalies. An action schedule has been developed and presented to the ISS Program management. The recommendations can be summarized as follows:

1. Identify, establish, and implement meaningful anomaly process metrics, as well as a Quarterly Management Review (QMR) where ISS Program management can evaluate open anomalies and assess how well the subsystem teams are managing/mitigating risks, etc.
2. Implement improved trending requirements and a trending program for system performance and anomalies.
3. Update existing requirements documents work instructions to ensure they reflect the as-executed processes and there are no inconsistencies between documents.
4. Improve the ISS anomaly reporting databases and associated tools to ensure they can support the long-term sustaining of the ISS.
5. Update generic and specific discipline training for all personnel involved in the anomaly resolution process to ensure the training is consistent with the requirements and processes.

STATUS

Anomaly resolution metrics have been identified and are in the final stages of review. Plans are in place to establish a QMR where management can evaluate open anomalies and assess how well the subsystem teams are managing/mitigating risks, etc.

Plans have been developed to address quality processes and technical criteria related to problem tracking and anomaly resolution processes, system performance trending requirements, hardware processing and operations for hardware qualification, and certification limits and software process improvements. These plans are undergoing ISS Program management review with the intent to implement them in a timely fashion.

Improvements in ISS problem trending have been identified and initiated in response to Action ISS-6.

The ISS Program has also conducted a review of available anomaly resolution databases and tools that could be implemented to facilitate the anomaly resolution process. Discussions are taking place with the Space Shuttle Program with the intent to standardize the tools used by both programs for performing the same critical function.

FORWARD WORK

Continue efforts to implement recommendations from the process review and complete the anomaly reviews. This is being done with the goal of providing the Program with effective procedures and tools required to monitor, manage, and sustain the health of ISS.

SCHEDULE

Under review.

ISS Continuous Improvement Actions

ISS Continuous Improvement Action 6

Review ISS system performance trending requirements and implementation status and make recommendations for improvement.

BACKGROUND

The monitoring of trends in the performance of the International Space Station (ISS) is becoming increasingly important as the time of operation of its subsystems increases and its overall complexity grows. The grounding of the Shuttle fleet and potential effects on ISS resupply have heightened concern in this area. The ISS Program undertook the performance trending continuous improvement action to improve its capabilities and processes in acquiring, tracking, managing, reporting, reviewing, and using performance trending data in support of ISS planning, decision-making, and risk management.

Improvements in these areas are expected to facilitate The ISS Program's ability to detect and respond to trends or recurring events that could otherwise lead to an eventual failure or catastrophic occurrence without intervention. Performance trend data are also used for supportability planning in areas such as logistics, spares provisioning, reliability predictions, and resource management. These data can additionally be applied to help establish launch and increment readiness, and to support decisions in mission support and anomaly resolution. Performance trending is also considered to be essential for risk assessment and risk management.

ISS PROGRAM IMPLEMENTATION

The ISS Program is evaluating the use of databases that it currently uses in performance trending to determine improvements in capabilities and processes that are needed to detect and respond to trends and recurring events. The ISS Program is additionally assessing the adequacy of subsystem processes at the Mission Evaluation Room (MER) for acquiring, reducing, and using telemetry data to establish trends and support decisions required for ISS operation, models validation, anomaly resolution, and supportability. Additional reviews have been initiated to expose and examine recurring events that are identified through trending analysis. These reviews will be conducted with each of the ISS subsystem teams and will provide a forum in which to communicate trend relationships across subsystems.

STATUS

The ISS Program employs multiple databases in performance trending. These include the Software Program Notice (SPN), problem report (PR), nonconformance report (NCR), in-flight investigation (IFI), and/or problem reporting and corrective action (PRACA) databases. The PRACA database allows trend analysis on types of failures, materials, defects, causes, recurrences, and test operations. The data can be evaluated on an increment-by-increment basis and sorted by system, subsystem, orbital replaceable unit (ORU), and organization. The ISS Program is currently evaluating the use and applicability of these databases to determine improvements that are needed in capabilities, processes, and practices to support performance trending.

Performance trends based on telemetry from the on-orbit system are used by ISS subsystems at the MER to establish operational baselines, determine relationships between measured parameters, validate models, and provide early warning of out-of-limit conditions. As part of the Performance Trending Continuous Improvement Action, the adequacy of subsystem processes will be assessed for acquiring, reducing, and using telemetry data to establish trends and support decisions required for ISS operation, anomaly resolution, and supportability.

The ISS Boeing Chief Engineer's Office recently initiated systematic reviews of recurring events. The Recurring Event Reviews are being conducted with each of the ISS subsystem teams. Recurring events are those anomalous repetitive situations that were either experienced on the ground or on orbit and are documented in the SPN, PR, NCR, IFI, and/or PRACA databases. These recurrent events are being analyzed at the integrated stage, element, system, subsystem, ORU, or component level. Periodic briefings will be given to ISS Program management on the results of the Recurring Event Reviews. The management briefings will include:

1. Trending analysis and results

2. Root cause
3. Consequence and impacts
4. Corrective Actions/Workarounds
5. Actions to restore functionality
6. Risk identified on 5×5 ISS Program Risk Matrix

FORWARD WORK

The ISS Program will continue to evaluate and refine the use of databases, telemetry, communications, reviews, processes, and practices in support of performance trending. This continuous improvement action is expected to help expose trends that could require intervention to avoid a more serious condition. Processes, practices, tools, and communication improvements that could facilitate system engineering and integration by exposing trend relationships across subsystems will also be explored.

SCHEDULE

Under review.

ISS Continuous Improvement Actions

ISS Continuous Improvement Action 7

The ISS Program will assess its hardware (ground and on orbit) to verify that it is within the hardware qualification and certification limits in light of the grounding of the Space Shuttle fleet. Where life limits are approaching, appropriate action will be taken.

BACKGROUND

Some International Space Station (ISS) hardware now awaiting launch at Kennedy Space Center have a limited shelf life, such as the electrical power system batteries and solar array wings. A limited set of hardware on orbit is designed for periodic replacement and, therefore, carries certification limits that affect its useful life. With the grounding of the Space Shuttle fleet, the ISS Program has systematically reviewed hardware certification limits and taken the necessary actions.

The ISS Program has established on-ground preventative maintenance requirements for spare hardware that is still on the ground and is not integrated into larger elements. However, no on-ground preventative maintenance requirements exist for hardware once the hardware is integrated into larger elements, such as truss sections. Launch delays due to the *Columbia* accident have driven the ISS Program to assess and define the preventative maintenance requirements for integrated hardware waiting for launch. The ISS Program is taking action to meet these requirements to gain the confidence that integrated hardware will function as required when assembled on ISS.

Within weeks of the *Columbia* tragedy, all on-orbit hardware with certification limits was reviewed. Where additional testing or analyses could be done to extend these certification limits, this testing and analysis was approved and performed. Where this was not possible, strategies and justifications were developed to allow continued use of these items in an acceptable manner.

ISS PROGRAM IMPLEMENTATION

Systematic reviews were completed by each ISS subsystem to determine needs for on-ground preventative maintenance, battery boost charging, reconditioning of batteries, extension of limited storage life requirements, and additional checkouts due to launch delays. The reviews involved an item-by-item and flight-by-flight re-evaluation of ISS hardware relative to these areas and identified recommendations for new requirements, storage life extensions, and confidence checks. The Space Station Program Control Board has agreed to actions to meet these new requirements.

STATUS

The ISS Program assessed the impacts to electrical power system batteries for various storage options, and is implementing procedures to minimize degradation. Although the batteries will have some degradation, the planned approach should allow the batteries to meet all Program needs. Additional options are still being explored, and are driven by the length of time to launch.

On June 26–27, 2003, the right and left blanket boxes of flight wing number five were successfully deployed. Based on the test results and analysis, the ISS Program extended the acceptable storage limit to 63 months. Options are currently being pursued for extending the storage limit to 82 months.

The ISS Program reviewed all systems and expanded on the original preventative maintenance to also address recommendations for confidence tests due to launch delays. For hardware integrated into carriers, the ISS Program deintegrated the hardware and is performing the maintenance per our nominal logistics processes, and has established reintegration milestones to occur once launch dates finalize. Based on these assessments, a new set of preflight confidence tests may be added to the Program.

FORWARD WORK

All activities associated with life violations due to launch delays are ongoing and will continue until new launch dates are established.

SCHEDULE

Due Date	Activity/Deliverable
Mar 2003	Review Certification Limits of On-Orbit Hardware
Continuous	Perform preventative maintenance, as required, to ensure ISS hardware waiting for launch will function properly on orbit

ISS Continuous Improvement Actions

ISS Continuous Improvement Action 8

Review lessons learned from ISS operations and identify any enhancements to ISS hardware or software that significantly mitigate risk to crew safety and mission success. Survey ISS system teams to identify any further modifications to hardware or software that reduce risk.

BACKGROUND

Enhancements to the International Space Station (ISS) design go beyond those which are required to meet ISS Program requirements and significantly mitigate risk to crew safety or mission success. To identify improvement candidates, the ISS Program conducted a bottom-up review and selected several proposals for implementation. The total list of suggested improvements will serve as an input to the ISS Planned Product Performance Improvements (P^3I) process.

ISS PROGRAM IMPLEMENTATION

This review was conducted in two phases. The first phase consisted of an independent review by ISS operations, engineering, and safety personnel of system design deficiencies and operational techniques that represent significant risk to the crew or to the vehicle. Potential hardware or software modifications that would mitigate the risk were identified. These potential modifications, called ISS enhancements, were intended to reduce risks to crew safety and mission success. Flight controllers from the Mission Operations Directorate and engineers in the Mission Evaluation Room in the Mission Control Center reviewed on-orbit system performance, known software deficiencies, and lessons learned from on-orbit operations to identify ISS enhancements. Safety engineers reviewed hazard reports and nonconformance reports to identify ISS enhancements. Inputs from each organization were compiled, and the results were reviewed and grouped in three categories. These categories are enhancements that:

1. Should be assessed by the Program immediately due to the potential for significant risk reduction.
2. Are covered by ongoing work.
3. Have potential benefits but do not merit immediate Program action.

Enhancements recommended for immediate Program review were presented to the Space Station Program Control Board (SSPCB). These included enhancements to External Active Thermal Control System redundancy and enhancements to the oxygen system on board ISS. The SSPCB directed further study of the technical solution and estimated cost of each recommended enhancement. Enhancements covered by ongoing work were left to work through normal processes.

Phase 2 of the ISS enhancements entailed soliciting recommendations from each system team to review risks and bring forward suggested ISS enhancements to mitigate these risks. These included additional infrared sensing equipment for internal and external use on board the ISS and External Active Thermal Control System redundancy. The SSPCB directed further study of the technical solution and estimated cost of each recommended enhancement.

STATUS

Several ISS enhancements have been approved for implementation, and detailed design and development work has begun.

Examples of approved enhancements are:

1. Electrical power jumpers to increase robustness in the case of certain failures.
2. Software modifications to facilitate recovery from a lockup of the thermal rotary joint.
3. Oxygen system outlet hose that includes a check valve to reduce the risk that contamination could cause a problem with the ISS oxygen system.
4. Detailed design of infrared cameras for internal and external use on the ISS.

FORWARD WORK

The ISS Program will ensure that the P^3I process captures suggested enhancements, and is continually reviewing suggested enhancements to reduce the risks associated with operating the ISS.

SCHEDULE

Due Date	Activity/Deliverable
Sep 2003	Recommendations for ISS enhancements to SSPCB
Under Review	Implement approved enhancements

ISS Continuous Improvement Actions

ISS Continuous Improvement Action 9

Review ISS Program and supporting organization contingency action plans and update them based on *Columbia* mishap lessons learned.

BACKGROUND

This International Space Station (ISS) Program Contingency Action Plan documents the actions to be taken in the event an ISS contingency is declared. It defines the ISS Program's responsibilities in the areas of mishap reporting and the investigation process. The ISS Program has reviewed and updated its ISS Program Contingency Action Plan and the implementation plans that will be used by the investigation teams in support of the Board of Investigation.

Per NASA requirement, all Contingency Action Plans, including the ISS plan, are updated at least annually.

ISS PROGRAM IMPLEMENTATION

The ISS Program performed an extensive review of the ISS Contingency Action Plan during the March–July 2003 time frame to reflect lessons learned from the *Columbia* mishap and to convert the original Johnson Space Center (JSC)-ISS Lead Center Plan to an ISS Program Contingency Action Plan. The revised ISS Program Contingency Action Plan defines the lines of authority within the ISS Program Office for notifying NASA Headquarters of a potential ISS contingency and the responsible ISS officials who will lead a mishap investigation pending establishment of a formal Board of Investigation. International Space Station Program Office and ISS support offices/directorates personnel participated in the review and the update of this Plan.

The ISS Technical Action Center will lead technical activities associated with understanding the contingency and managing all technical actions. During this time, investigation teams that will be supporting the ISS Technical Action Center prepared and finalized their team's implementation plan. All ISS Program supporting organizations reviewed and updated their contingency action plans to be consistent with the ISS Contingency Action Plan.

The ISS Contingency Action Plan and its appendices, which contain contact information for NASA senior management, ISS Program, and JSC management personnel, have been updated and posted on an ISS server. The appendices also contain contact information for the chairpersons and alternates of the ISS Technical Action Center's investigation teams. Access to this information and to the implementation plan for the ISS Technical Action Center and its investigation team is available on the Increment Management Center Management Coordination Web site.

STATUS

As a result of this activity, the ISS Program Manager approved the updated ISS Program Contingency Action Plan in July 2003. Using this updated plan, a simulation of an off-nominal Soyuz landing was completed in October 2003.

FORWARD WORK

To enhance ISS Program preparedness in case of contingency, the following areas are being addressed:

1. NASA will ensure ISS International Partners are prepared to respond to an ISS Contingency Event.
2. NASA will continue to perform contingency simulations for both ground and on-orbit events.
3. The Mishap Investigation Team (MIT) is a small group of people from various disciplines. NASA will review MIT membership and supplemental support, and will include procedures in its contingency plan for quickly supplementing MIT activities with administrative, computer, and database support and debris management.
4. ISS will review updates to the Space Shuttle Program's Contingency Action Plan to identify any applicable improvements.

SCHEDULE

Due Date	Activity/Deliverable
Jul 2003	Release revised contingency action plan
Oct 2003	Conduct contingency simulation

ISS Continuous Improvement Actions

ISS Continuous Improvement Action 10

The ISS Program's avionics and software management organization will continue to evolve software development and integration processes to provide high-fidelity flight software suites with higher productivity. In addition, ISS software uplink and long-term sustaining processes will be updated to reflect lessons learned from ongoing ISS software upgrade activities.

BACKGROUND

The International Space Station (ISS) is a spacecraft that is comprised of elements provided by NASA, the Russian Space Agency, the European Space Agency, the Italian Space Agency, the Japanese Aerospace Exploration Agency, and the Canadian Space Agency. Operation of these diverse elements is integrated into a single spacecraft via the on-board software suite.

The U.S. portion of the ISS is controlled by computers, both inside and outside the pressurized modules, that use 20 different sets of software with over 2 million source lines of flight code. In aggregate, the Russians, Canadians, Italians, Europeans, and Japanese are providing computing capability of roughly equivalent size and complexity for a total ISS on-board software suite of 4 million source lines of code. The system is architected as a three-tier federated system that is managed as functional control zones. Due to the size and complexity of the software suite and the incremental development strategy, it is imperative that all development be highly structured to avoid on-orbit problems. Facilities in Houston replicate the significant aspects of each ISS configuration for overall software integration prior to uplink of the required functionality for that specific configuration.

Even though the initial ISS software has been on orbit for five years, providing excellent operational performance, we have instituted a continuous improvement program that will continue to provide the same high-fidelity software with even higher organizational productivity.

ISS PROGRAM IMPLEMENTATION

Development Process

Software for the ISS is developed per the Mil-Standard 2167A process. ISS uses the Software Engineering Institute (SEI) Capability Maturity Model (CMM) as the "measuring stick" by which to document the maturity of each developer's processes. The industry-accepted norm for a cost-effective, repeatable software developer is a CMM rating of level three.

Achieving each level in the SEI CMM process involves an assessment by knowledgeable individuals of the candidate organizations' policies, procedures, and performance data.

Integrated Testing

The Software Development and Integration Laboratory (SDIL) in Houston is used for the formal integration and certification of the flight software suite. It has a combination of flight-equivalent and actual flight hardware computers used in appropriate combinations to replicate the on-orbit spacecraft, enabling an in-depth evaluation and certification of the entire software suite.

Sustaining Approach

A block release approach is being used to plan and produce the sustaining software necessary to operate and maintain the spacecraft. The plan will produce three blocks of needed software sets per year in the near term, and taper to one per year as operational experience is gained. Once the software has completed certification, it is uplinked to replace the initial code.

STATUS

Development Process

The ISS Prime contractor software development sites are all at or above the desired Level 3. NASA is encouraging the Prime contractor to continue to strive for a Level 5 rating, and the contractor is working to achieve the infrastructure to support a Level 5 rating in Houston by December 2003. To actually achieve this rating requires several months of metric collection to demonstrate infrastructure effectiveness.

To date, over 1.25 million source lines of code have been developed and flown with minimal problems.

Sustaining

Due to the incremental assembly of the ISS, over 1 million lines of ISS code have been developed and replaced on ISS using the sustaining process. Lessons learned from these operations have been studied, and ISS software development and uplink processes have been improved as a result.

One of the primary lessons learned is that a process is needed to ensure that the best ideas for spacecraft operability enhancements receive priority for competing resources. Our approach is to use the existing Program Software Change Request system to develop a comprehensive list of proposed software product improvements in a coordinated and structured manner from all stake holders (crew, operations, engineering, and safety). The list will be prioritized to optimize the core software system for safety, speed, robustness, usability, and maintainability. The list will then be used for a coordinated content determination for each sustaining computer software configuration item release to implement the highest-priority software product improvements. The list will be a living document, with each new proposed change being evaluated against the existing priorities for placement of that change's relative priority.

Integrated Testing

The ISS is just completing Phase 1 of an enhancement project to enable the inclusion of additional flight computers and firmware controllers into the SDIL. Phase 1 expanded the laboratory floor space and control rooms, and replaced several flight-equivalent computers with flight prototypes for the ISS Systems Integration Laboratory of the SDIL. Phase 2 will continue to expand the software/hardware integration capability with additional flight computers and firmware controllers.

FORWARD WORK

Continue to rigorously pursue software process improvements and laboratory enhancements.

SCHEDULE

Under review.

ISS Continuous Improvement Actions

ISS Continuous Improvement Action 11

The ISS Program has implemented some initiatives to facilitate the reporting of occupational and on-orbit safety concerns by its employees.

BACKGROUND

Safety is paramount in the minds of all NASA employees. Each International Space Station (ISS) Program employee contributes to safe operation of the ISS through execution of their assigned responsibilities. Each employee is trained and encouraged to communicate safety concerns to their supervisor or team members. The purpose of a safety reporting system is to allow direct, effective communication of concerns. These concerns may be with flight hardware, software, or ground operations and personnel.

The ISS Program has implemented an approach to increase ISS Program employee awareness of established NASA safety reporting systems. The goal is to ensure that employees are encouraged to report any safety concerns, as well as to ensure that employees are aware of the NASA Safety Reporting System (NSRS) program availability.

ISS PROGRAM IMPLEMENTATION

The ISS Program has implemented a link from the ISS homepage. This page is also linked from other ISS office homepages. The ISS homepage clearly defines the steps that should be taken if a safety concern exists. These steps include:

1. Correct the situation yourself, if possible.
2. Report the situation to your supervisor.

If an employee feels that a situation has not been or cannot be addressed adequately at this level, or if they feel that further management visibility is warranted, they should contact:

1. The ISS Safety and Mission Assurance/ Problem Reporting Manager (contact information provided).
2. The ISS Program Manager (contact information provided).
3. The ISS Safety, Reliability and Quality Assurance Director (contact information provided).

If an employee has reported the concern and has seen no action, is not satisfied with the response, or fears reprisal, that employee has the option to submit an NSRS report.

Additionally, NASA has modified the Close-Call reporting system to accommodate anonymous reports related to ISS.

STATUS

A homepage has been developed and its status communicated to ISS personnel.

FORWARD WORK

Continue to make personnel aware of the methods available to report safety concerns, as well as to modify the communication methods as improvements are identified. Additionally, the ISS Program is evaluating options for placing proper emphasis on minority dissenting opinion, such as requiring minority dissenting opinions to be captured in meeting minutes as a standard practice.

SCHEDULE

Under review.

ISS Continuous Improvement Actions

ISS Continuous Improvement Action 12

The ISS Program has initiated action to make recommendations for improvements in quality assurance aspects of ISS development and operations.

BACKGROUND

The mission of International Space Station (ISS) Program quality assurance (QA) is to ensure the ISS Program maintains the necessary discipline in adhering to requirements and executing processes, thus contributing to overall technical excellence and the safety of the ISS vehicle and crew.

ISS PROGRAM IMPLEMENTATION

To accomplish our goals, high-quality processes must be established and effective QA activities must be in place. The ISS Program has identified the need to strengthen the QA role in management and implementation of its anomaly resolution processes. A specific action is in place to accomplish this.

Philosophical and organizational changes are being evaluated that will have a positive and value-added impact for quality in all aspects of ISS Program activity and functions. Our goal is to strengthen ISS QA activities while we embrace the following concepts:

1. A strong quality discipline within the ISS Program to accomplish nominal ISS QA and support anomaly resolution activities.
2. Adherence to requirements and processes is maintained within the ISS Program by all ISS Program organizations and personnel.
3. A knowledgeable and authoritative QA organization to assist all elements of the ISS Program.

STATUS

The ISS Program has developed plans to address quality processes and technical criteria related to problem tracking and anomaly resolution processes, system performance trending requirements, hardware processing and operations for hardware qualification and certification limits, and software process improvements. Specifically, plans have been developed to:

1. Provide a staff of full-time quality staff in support of the QA processes, including anomaly resolution.
2. Pursue an experienced QA skill base to enhance the implementation of the level of QA needed to ensure effectiveness of quality processes.
3. Enhance the training of engineering and QA personnel who are involved in the processes—either through development of training modules or emphasis upon existing training of the importance of adherence to already defined processes.

FORWARD WORK

The ISS Program will continue to identify and evaluate all processes related to operating and sustaining the ISS.

SCHEDULE

Under review.

ISS Continuous Improvement Actions

ISS Continuous Improvement Action 13

The ISS Program will assess its process for tracking Top Program Risks via the existing ISS risk management tool, specifically the Integrated Risk Management Application, and recommend improvements where necessary.

BACKGROUND

The purpose of risk management is to identify risks early in the Program so that appropriate mitigation plans can be put into place to effectively reduce the risk or prevent the risk from occurring. The risk management process provides systematic methods for identifying, analyzing, planning, tracking, controlling, and communicating and documenting risks.

ISS PROGRAM IMPLEMENTATION

Every International Space Station (ISS) managing organization is involved in risk management. The managing organization uses the ISS risk database to manage and communicate risk data. A characterization of each risk, its likelihood/consequence scoring, and the mitigation tasks are entered into this database. Individual risks are plotted on a risk matrix to provide a visual representation of the relative importance of each risk so that a managing organization and ISS Program management can readily determine where intervention or resources are required. The overall top risks of the ISS Program are captured in the Top Program Risk (TPR) matrix.

The TPR matrix accumulates the current major issues that the ISS Program is managing. TPRs are risks that significantly affect the safety of flight, ISS Program budget, schedule, crew health, integrity of the ISS hardware/software, or mission success. TPRs are also risks that require significant ISS Program resources and attention. The TPRs are evaluated at each Program Risk Advisory Board (PRAB) meeting, which is held approximately every six weeks, where all top risks are discussed, integrated, and planned and appropriate resources and attention can be brought to mitigate the risk.

The ISS Program Manager reviews plans to mitigate the risk, and the approved abatement plan is entered into the ISS risk database, where it is tracked by the managing organization. Resources are assigned to effectively manage the risk.

When all abatement tasks have been met or accomplished, the PRAB closes the risk. The managing organization accomplishes this action in the ISS risk database. The PRAB may also accept the TPR. Accepting a risk means that the ISS Program cannot implement a cohesive abatement plan or that the resources required do not warrant further management of the risk.

The managing organization for a risk continues the abatement process for the TPR with periodic updates. This process continues until ISS Program management *closes*, *accepts*, or *mitigates* each risk to an acceptable level through the PRAB process. Either acceptance or closure action is accomplished by the managing organization and is documented in the ISS risk database.

There are other ISS processes that also capture and document accepted Program risks that are not currently documented in the Integrated Risk Management Application. Other safety and mission assurance processes that capture accepted risk include the approval of nonconformance reports; the approval of waivers, deviations, and exceptions; and also the approval of critical items documented on the critical items list (CIL). NASA is reviewing these items to determine which have potentially catastrophic consequences with a start time to effect and should be defined as TPRs for increased visibility.

STATUS

NASA is reviewing all accepted, mitigated, and closed risks in the safety, quality, and reliability areas to determine where significant risk (i.e. catastrophic consequences with a short time to effect) has been accepted and whether these items should be reopened to mitigate the risk further. Accepted risks that carry catastrophic consequences with a short time to effect will be captured in the ISS risk management process to ensure that they are regularly reviewed.

FORWARD WORK

Complete review of critical items; nonconformance reports; and waivers, deviations, and exceptions. The risk contained in these exemptions will be reviewed by the ISS Program at regular intervals. As the ISS Program identifies new nonconformance reports, CILs, and waivers, the Program will evaluate those items for incorporation into the risk management process as well.

Additionally, as part of the Certification of Flight Readiness process, all open or accepted risks will be presented to the ISS Program Manager for concurrence or restrictions in the flight or operations. These risks include those risks that have been previously accepted. For each flight, all accepted risks will require the ISS Program Manager's approval and will be placed under configuration control.

SCHEDULE

Under review.

Appendix A: NASA's ISS Continuing Flight Process

BACKGROUND

Reaping the lessons learned from the *Columbia* accident and the *Columbia* Accident Investigation Board's (CAIB's) findings started immediately after the accident. While the CAIB was conducting its investigation, the International Space Station (ISS) Program began an intensive effort to examine its own processes and operations to reduce risk under a continuous improvement initiative. As the CAIB released its preliminary findings, the ISS Program assessed them for applicability. Other continuous improvement activities were derived from the experience the ISS Program has gained from 3 years of crewed ISS operations and 5 years of system operation.

Major General Michael C. Kostelnik, USAF, Retired, Deputy Associate Administrator for ISS and Space Shuttle Programs chartered the Continuing Flight Team (CFT) under the leadership of Mr. Albert D. Sofge. The CFT will review the output of the CAIB Report and determine the areas that are applicable to the ISS Program and ensure there are actions in place addressing those outputs.

CONTINUING FLIGHT TEAM DUTIES

The CFT will:

- Assess the CAIB Report for applicability to the ISS Program.
- Review ISS Program posture with respect to the applicability to the Report.
- Ensure ISS Program actions are in place to address applicable areas of the Report.
- Document its assessment.

CONTINUING FLIGHT TEAM PROCESS

The CFT will review the CAIB Report and will work in concert with the ISS Program to develop alternative options and proposals for the DAA, ISS and Space Shuttle Programs and the Space Flight Leadership Council (SFLC), as required, for addressing change requirements. The ISS Program Manager or Space Shuttle Program Manager will implement the approved change requirements, as appropriate.

The CFT will utilize existing ISS Program boards and panels as required to provide information and analysis. The ISS Program will provide administrative support, including action tracking, to the CFT. The CFT Lead and the ISS Program Manager will work closely to ensure full coordination of the CFT efforts across the Program elements.

SPACE FLIGHT LEADERSHIP COUNCIL

Cochaired by the Associate Administrator for Space Flight and the Associate Deputy Administrator for Technical Programs, the SFLC will provide guidance resulting from insights into ISS and Space Shuttle operations, and mission requirements. The SFLC may also direct independent analysis on technical issues related to CFT issues. The membership of the SFLC includes the OSF Center Directors (Johnson Space Center, Kennedy Space Center, Marshall Space Flight Center, and Stennis Space Center) and the Associate Administrator for Safety and Mission Assurance. SFLC meetings are scheduled as needed.

CFT SCHEDULE

To be supplied.